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Demographic Dividends, Human Capital, and Saving

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Introduction and Background

Both rich and developing countries are experiencing dramatic changes in population age structure as a consequence of the demographic transition, post-world war II baby booms and busts, the emergence of very low fertility, and continuing improvements in life expectancy. All these changes combine transitory swings in age distribution with a secular trend toward aging populations. These changes bring both opportunities for intensified investments in human and physical capital to promote economic growth and challenges as support systems for the elderly are stressed and labor force growth slows or turns negative. Investment in human capital through mass formal education has increased dramatically in both developing countries over the past century and rich industrial nations over the past two centuries. On the one hand, increased human capital substitutes for the reduced supply of workers, and on the other hand the increase may be closely tied to the demographic forces that are leading to population aging, declining fertility and mortality. Health is another dimension of human capital, and investments in it have grown dramatically as well.

In Lee and Mason (2010) we used a stylized three age group OLG model in the spirit of Becker and Barro (1988), calibrated on data for nineteen countries around the world from the National Transfers Account project (NTA), to simulate the relation between human capital investment and demographic change over the demographic transition. We investigated the extent to which increased quality of workers might offset the falling support ratio due to slowing growth of quantity of labor. We found that under some plausible parameter values higher human capital could substantially offset the lower growth trajectory of workers. One goal of this paper is to refine and to elaborate on the analysis of human capital. We carry out a more detailed analysis of the relation of human capital spending to demographic and economic change. We are able to draw on data for 39 NTA countries, in contrast to the nineteen with the necessary data in the 2010 study, permitting a more detailed analysis, treating public expenditures and private expenditures separately, and considering the role of per capita income as well as fertility and child dependency in relation to human capital spending. The analysis is used in a more realistic simulation that shows how human capital investment has varied in relation to the changing demography from 1950 to the present, and how it might be expected to change over the rest of this century, particularly up to 2050.

A second goal of this paper is to provide a more comprehensive model that incorporates both human and physical capital. In our past work, we have treated these separately while acknowledging the importance of both. Here we consider both. This will improve our understanding of the economic implications of the demographic dividend and particularly the “second demographic dividend”, the term we use to refer to a second round of adjustments for the changing population age distributions over the demographic transition, including investment in human and physical capital, and increasing female labor supply.[1]

At the end of this paper we compare our approach and results to those from a similar study by Ashraf, Weil and Wilde (2013). [2]

Implementation and key results

The objectives of the paper are realized by simulating the development of a hypothetical economy during its transition from very high fertility and poverty to low fertility and higher standards of living. Realistic demography is incorporated into the model by using UN population estimates and projections for Nigeria, where the TFR remains above six births per woman. The economic model is generic, designed to capture important connections between population and economic development that are highlighted in the literature on demographic dividends. With minor exception, the model parameters are based on previous research and updated estimates of the relationship between human capital investment and fertility based on National Transfer Accounts data for many countries. The economic model does not incorporate any idiosyncratic features of the Nigerian economy.

A baseline simulation tracks economic outcomes in the event that fertility does not decline from its current level. This simulation is of interest only as a baseline against which we can compare alternative fertility scenarios. Any differences between simulations are attributable only to differences in fertility and the accompanying changes in human capital. It should be kept in mind, however, that fertility decline interacts with other variables in influencing the pace of development. Two of the fertility scenarios are based on alternative UN population projections – the medium and low fertility scenarios for Nigeria. The third scenario explores the possibility of radical fertility decline based on the experience in China during its unprecedented fertility transition.

The analysis shows fertility decline accompanied by an increase in human capital spending provides a substantial boost to economic growth. Some of the enhancement comes over the first thirty years as a consequence of the first demographic dividend. Given the low or medium fertility scenario per capita consumption will grow more rapidly by 0.4 to 0.6 percentage points between 2010 and 2040. The biggest gains come later, however. Per capita consumption growth is higher by about 1.5 percentage points between 2040 and 2100, the end point of the simulation. The large gains are a consequence of the second demographic dividend – the economic growth due to greater investment in physical and human

[1] Terminology differs, and some analysts include these effects in a single "demographic dividend".

[2] David Weil, one of the authors of this paper, suggested that we include a simulation of the effects of the United Nations Low Fertility scenario which would make it possible to compare results to the Ashraf, Weil and Wilde (2013) paper. This comparison is now included.

capital. Radical fertility decline would produce gains that come earlier and would be substantially greater.

Background: Human capital and economic growth

Does human capital foster economic growth?

A large literature has investigated the influence of education on economic growth through cross-national regressions (see review by Hanushek and Woessmann, 2010, 2012). Measuring educational attainment by mean years of schooling, as in the Barro-Lee (2010) data set, cross-national regressions typically find a robust positive effect on the rate of economic growth. Results are strengthened by refinement of the measure of educational attainment (Lutz, Cuaresma et al. 2008). These effects are even stronger and more consistent when a measure of cognitive ability is used in place of grade attainment (Hanushek and Woessmann, 2010, 2012). There are critics of this line of research (Wolf 2004; Aghion, Boustan et al. 2009). In this paper we will simply assume that human capital (past investments in health and education) enters an aggregate production function as will be explained later and, thereby, contributes to economic growth.

Measurement

National Transfer Accounts takes a different approach than the studies mentioned above. The NTA estimates are based on estimates of public and private education and health expenditures on individuals by single years of age. Total human capital investment in each year is equal to total public and private spending on education and health of children and, in the case of education, young adults. Human capital of each cohort depends on the cumulative investment in the human capital to date in that cohort adjusted to reflect the extent to which members of the cohort are members of the workforce. Investment in human capital and the stock of human capital are, thus, treated in a fashion very similar to investment and the stock of physical capital.

Our NTA measure of human capital investment is dictated by the NTA accounting framework which provides comprehensive estimates of the costs or economic resources devoted to achieving education and health outcomes. NTA estimates do not include the value of the time of students nor do they include the value of the time of parents or grandparents who surely contribute to human capital of children and grandchildren.

The NTA educational expenditure measure described above should contain some useful information about quality of education, an important dimension. It also allows us to consider public and private investment data separately which may not be so important for European countries but which is extremely important in some other parts of the world such as East Asia, where private spending exceeds public in China, Taiwan, and South Korea although not Japan.

Fertility and Human Capital: The quantity-quality tradeoff

Becker's (1959) seminal paper introduced the idea that parents care about both the number and quality of their children, but the implications of this insight were not developed until Becker and Lewis (1973) and Willis (1973). Prettner, Bloom et al. (2013) build on these insights in a more recent study. These analyses developed the consequences of the multiplicative interaction of quantity and quality of children in the family budget constraint, with each affecting the shadow price of the other. The demand for both numbers of children and average quality per child are posited to have positive income elasticities. However, the income elasticity of quality is assumed to be higher than that of quantity, and because each affects the shadow price of the other, expenditures on quality per child rise while the number of children falls. In this account the rise in quality and fall in quantity are both caused by the rise in income. However, we could easily imagine circumstances in which exogenous influences on fertility such as access to superior contraception, or on quality such as public subsidies of schools, might result in a fertility change causing a change in quality, or the reverse. We expect that actual changes in income, fertility, and human capital will be reflecting some degree of causality through each of these channels.

In these analyses (for example, Becker, 1981) the "quality" of a child was just a shorthand way of referring to parental expenditures on the child. Significantly, Becker and Barro (1988:9) distinguish between "child-rearing costs that do not involve human capital" and parental expenditures on a child that do raise its human capital and influence the wage the child earns later in life, noting that "Practically all families invest in the human capital of children - a form of 'bequest' that is far more common than transfers of assets**".** In our implementation of the quantity-quality tradeoff and investment in human capital of children, we are guided by this important distinction. We distinguish between parental expenditures on health and education per child, which we consider to be human capital enhancing, and the remainder of expenditures per child, for example on housing, food, clothing, entertainment and recreation.

The quantity-quality tradeoff theory was originally intended to apply to decisions about private expenditures on human capital. However, it is arguable that the private demand for education drives public expenditures on it, in which case it would be subject to the same sort of quantity-quality tradeoff as private expenditures on education. In addition, we believe that cultural, historical and political differences across countries and regions influence the relative roles of public and private spending on education.

Parents must take public expenditures on education and health as given when they make their own private decisions about their own expenditures for these. However, it is not obvious how this would play out. We might suppose that parents would choose higher fertility when there is a public human capital subsidy because it would reduce the shadow price of quantity (due to the reduced average price of quality). But perhaps complementary private expenditures are needed to take advantage of public education (transportation, school uniforms and books, medical certificates) such that private expenditures on quality end up being higher than before the subsidy, and fertility lower. There might be an income effect since the government now pays for at least a part of quality, but taxes would have to be raised at the same time and the net outcome is not clear. If there is an income effect on fertility, the theory predicts it will lead to lower fertility and higher quality. The upshot is that theory gives no clear prediction on how public education might affect fertility and private spending on education.

Human Capital and the Second Demographic Dividend

Changing population age distributions across the demographic transition have been mainly driven by changes in fertility and mortality. One aspect of these changes is the decreasing share of children in the population once fertility falls, a decrease partially offset by increasing child survival.[3] The quantity-quality theory leads us to expect that expenditures per child on health and education will correspondingly rise. The compositional benefits of the rising support ratio in mid-transition are only transitory, but to the extent that these same age distribution changes also promote increased investment in physical and human capital, the gains may be preserved and amplified. In particular, rising investments in human capital may raise the quality and productivity of the work force and offset the decline in relative numbers of workers, at least in part.

A growing empirical literature has explored these possibilities.[4] Lee and Mason (2010), described earlier, used NTA data for 19 countries to estimate an elasticity of -1.05, not significantly different than -1, between total fertility and the sum of public and private human capital expenditure per child. In their model, human capital spending in each country was expressed in YoLY, that is years of average labor income for ages 30 to 49. This measure was then regressed on the period Total Fertility Rate (TFR) five years earlier in a double log specification.

[3] At the very start of the transition, fertility typically remains high as mortality begins to decline, which leads to a rising share of children in the population.

[4] There have been two recent simulation studies of OLG models with endogenous education. In Prettner and Prskawetz (2009) young workers choose fertility and human capital investment per child, but their model does not include public or private transfers to the elderly who instead rely on earlier savings. The outcome is that lower fertility and population aging go with higher investment in human capital and intensification of physical capital and therefore higher per capita income. The question whether increased human capital compensates for and offsets the reduced share of the working age population does not arise, and the focus of the paper is instead on the relative wages of younger and older workers who are not perfect substitutes. A study by Fougère et al (2009) develops a more elaborate OLG model with endogenous education, but education decisions do not depend in this model on the exogenous level of fertility. Thus these interesting studies are not relevant for this paper.

Capital and the Second Demographic Dividend

Lower fertility and slower population growth promote investment in human capital per child as we have just seen, and they also lead to increases in the amount of physical capital per worker. There are several ways to see this, from the compositional effect of population aging, from the perspective of individual behavior, and from a macroeconomic perspective.

In all countries in the NTA dataset, asset income rises strongly with age which indicates that asset holdings rise strongly with age as well, reflecting the tendency for adults to save and accumulate assets as they age. People accumulate assets for many reasons – to provide for consumption in old age, as a buffer against health costs and other unforeseen financial needs, to leave a bequest for descendants, or for any number of other reasons. As a population ages and the ratio of elderly to working age population rises, this age pattern of asset holdings means that the ratio of assets to workers and to the general population also rises. If the economy is at least partially closed, and if some part of the assets is held in the form of capital, then the productivity of workers may be raised. In any event, asset income per capita will rise, raising per capita income. This is the compositional effect. In addition, we might expect increased saving and asset accumulation for behavioral reasons arising from fewer children and longer life (Lee, Mason and Miller, 2003).

Population aging also affects saving or capital per worker in macroeconomic models, with results of course depending on the assumptions made. The simplest setup is the Solow growth model with a constant aggregate net saving rate. In this case, the slower population growth that generates population aging implies an increase in capital per worker. An alternative assumption is that the capital-output ratio remains constant, which is approximately true over fairly long periods in OECD countries, but has not held recently and has been strongly challenged by Piketty (2014). On this assumption, the capital-labor ratio increases but less so than under the constant saving rate assumption. In addition, the saving rate is reduced just enough to keep the capital-output ratio constant allowing for an additional effect on consumption. With either constant savings rate or constant capital-output ratio, slower population growth generates a "second dividend" with higher consumption (Lee, Mason, et al. 2013). In our simulations to be described in a later section, we will assume that the capital-output ratio is constant.

The Quantity-Quality Tradeoff in NTA data

National Transfer Accounts provides estimates of public and private spending on health and education by age. In Lee and Mason (2010) we used a synthetic cohort measure of human capital investment constructed by summing over age in the cross-sectional profile of health expenditure from ages 0 to 17[5] and for educational expenditure from 3 to 26. These sums were then expressed in YoLYs (the years of

[5] For health, ages greater than 17 are excluded because of ambiguity about the treatment of maternal health care. Should it be counted as human capital income in the mother? The child? We have elected to exclude it.

average labor income of an adult 30-49). For example, in the US in 2003 average labor income per adult for those 30-49 was $47,116. The human capital investment in raising a child, based on our synthetic cohort measure was $182,000 or 3.9 YoLYs. In contrast, the human capital cost of a child in Kenya in 2005 was $3684 or 1.3 YolYs . Measured In YoLYs, the US was investing 3 times as much in human capital as was Kenya. Measured in ppp dollars, the US was investing 50 times as much as Kenya.

One motivation for expressing human capital investment in YoLYs is that it allows direct comparison of the allocation decisions of countries with very different levels of income. Another potentially important use is that it controls in a crude fashion for across country variation in labor costs, very important in education and health.

Per capita spending by age for health and education, public and private, is presented in Figure 1. The left panel is the average value for 15 high income countries while the right panel is the average value for 24 middle and low income countries. (See the appendix for a complete list of countries and selected data for those countries.) Spending per child in YoLYs is higher in high income countries. Human capital spending is somewhat elevated for infants due to health care spending. In both country groups, human capital spending rises sharply with age as children enter school and declines as children and young adults depart school.

Government spending on education (CGE) followed by familial spending on education (CFE) are the largest components of human capital spending. In the high income countries, public human capital spending (CGE+CGH) is greater at all ages than private spending (CFE+CFH), but that is not the case in middle and lower income countries included in our data. In general, private spending is more important relative to public spending in middle and lower income countries than in high income countries. For older youth, private spending on health and education exceeds public spending in middle and lower income countries.

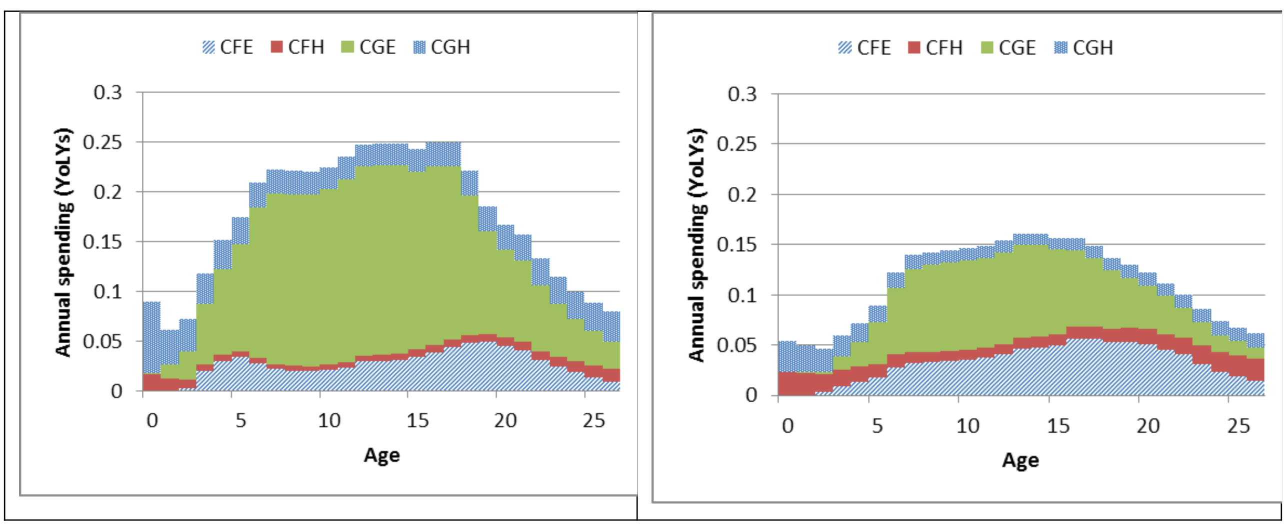

Figure 1. Components of human capital spending by age (0-26) in high-income (left figure) and middle- and low-income (right figure) countries: Private education (CFE), private health (CFH), public education (CGe), and public health (CGH). All values expressed in YoLYs – average of labor income per person age 30-49. Source: Calculated by authors. File: ntadata.xlsx

Synthetic cohort values of human capital spending are reported for high income countries and middle and low income countries in Table 1. In high income countries human capital spending is 4.4 YoLYs on average and 2.8 YoLYs in middle and low income countries. As is apparent in the age profiles presented above, expenditure on education is far more important than health in both country groups. For every YoLY devoted to health we see about six YoLYs devoted to education in high income countries and four YoLYs in middle and low income countries.

Table 1. Spending on human capital, synthetic cohort values, expressed in YoLYs.

	Education	Health	Total
	High income		
Public	3.02	0.50	3.52
Private	0.72	0.13	0.85
Total	3.74	0.63	4.37
	Middle and low income		
Public	1.37	0.28	1.65
Private	0.86	0.24	1.10
Total	2.23	0.52	2.75

The public sector is dominant in high income countries accounting for about 80 percent of human capital spending. The public sector in middle and low income countries accounts for about 60 percent of human capital spending. A very surprising feature of these data is that the human capital spending advantage of high income countries (measured in YoLYs) is entirely due to public spending. Private spending is greater for both health and education in middle and low income countries than it is in high income countries.

The shift in human capital investment from private to public hands is a very important phenomenon. We explore this further in Figure 2 by plotting the share of human capital spending from public sources against the natural log of YoLY. When we normalize on the YoLY, as in Figure 1, the unit or currency is irrelevant so long as the numerator and denominator are the same. Here, however, the YoLY is being used as an age-independent comparative measure of development and it is necessary to use a common currency. For this purpose we have used US dollars in thousands to construct the YoLY. There is a great deal of variation in the importance of the public sector, but reliance on the public sector clearly increases as countries develop. A striking feature of the results presented in Figure 2 is that the diversity is much diminished among high income countries. In continental Europe public spending is clearly more important and private spending less important than in other high income countries.

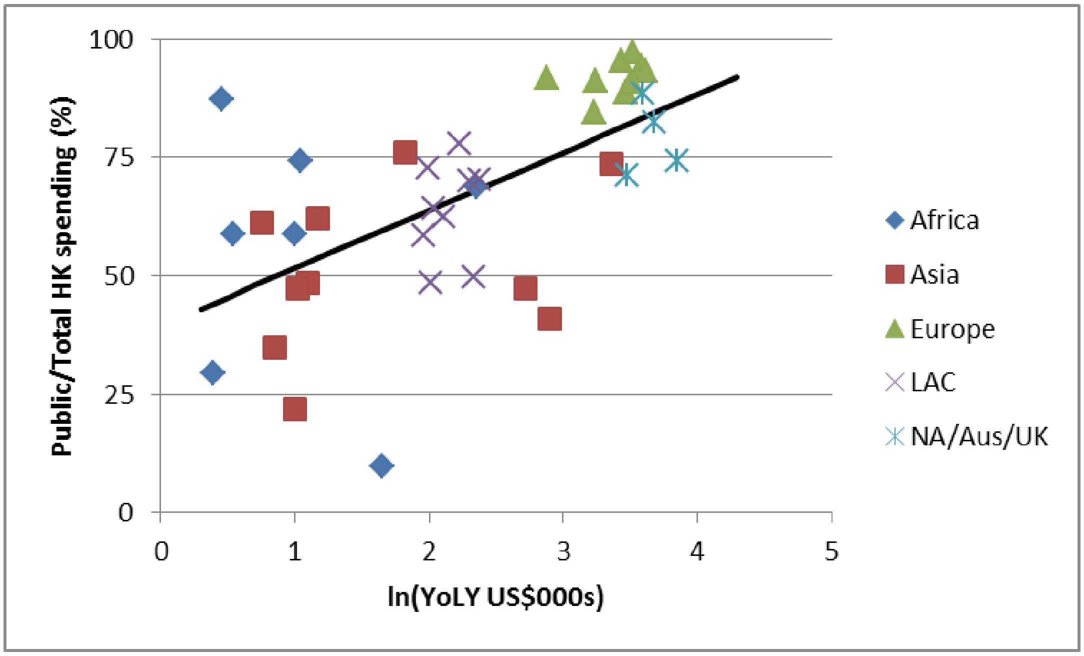

Figure 2. Public human capital spending as a percentage of total human capital spending versus the natural log of YoLYs measured in $US 1000s. Human capital spending are synthetic cohort measures as described in the text. Source: National Transfer Accounts www.ntaccounts.org. File: ntadata.xlsx.

Human capital spending is particularly salient in aging societies because they have very low fertility and the quantity-quality tradeoff therefore implies high human capital investment. Under these circumstances, aging populations will have smaller cohorts of workers but ones in whom much more has been invested. The simple relationship between fertility (quantity) and human capital investment (quality) can be seen in Figure 3 which plots the synthetic measure of human capital expenditure in YoLYs against the total fertility rates for the 39 countries in our cross-sectional data. This figure is an update of a similar figure based on NTA data for 19 countries in Lee and Mason (2010). The estimated elasticity is -0.74 – a one percent decline in fertility leads to a 0.74 percent increase in human capital spending per child.

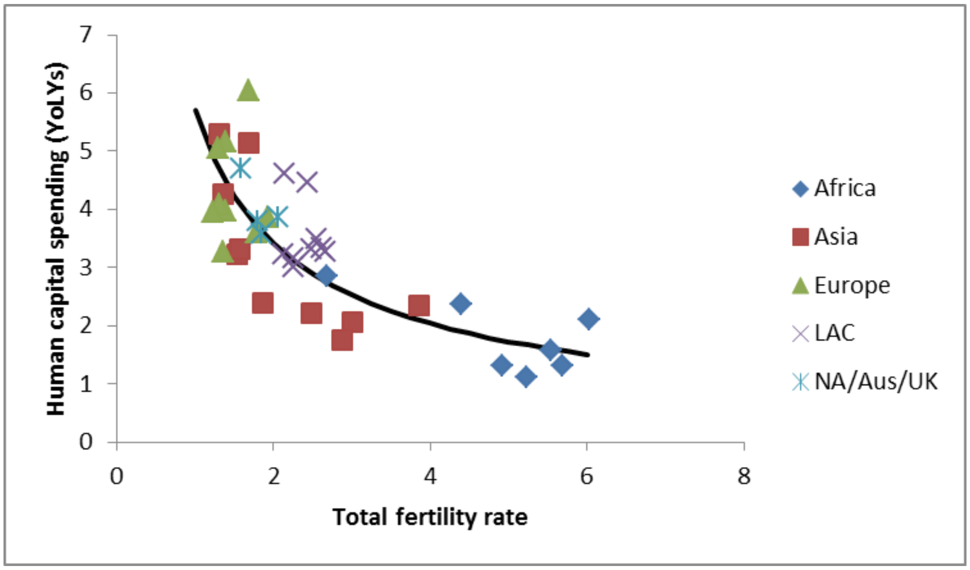

Figure 3. Total human capital spending versus total fertility, 39 countries. Fitted line is constructed by regressing ln of human capital on ln TFR. Estimated elasticity is -0.74. Source: Calculated by authors. File: ntadata.xlsx

The analysis presented below looks in more detail at the correlates of human capital spending. The amount of data is still limited with only 39 countries, and the results presented here are intended as purely descriptive with the emphasis on the role of age structure. Our previous analysis (Lee and Mason, 2010) considered only combined public and private spending, but here we will analyze public and private spending separately. In previous work we controlled directly for differences in income by measuring investment in YoLYs as in Figure 3. Here we will allow human capital spending to vary both with income (as measured by YoLYs or the mean labor income of persons 30-49) and the total fertility rate (TFR). We also extend the analysis to consider the potential effects of population aging, as measured by the child-dependency ratio and the old-age dependency ratio, on human capital spending.

Specifying and interpreting the human capital equation

In what might be called the pedagogical version of Becker's (1991) quantity-quality theory, a couple first decides what fraction $1\text{-}w$ of family income Y to devote to its own consumption, and next decides how to allocate the balance wY between quantity and quality of children. In this case, for a given level of family income, then quality is inversely proportional to quantity. Suppose that the income share devoted to children is the same at all levels of income. Regardless of the source of variation in the two, they will always lie on the line defined by $H = wY/N$, where N is the number of children and H is human capital per child, or quality. Dividing both sides by Y we get $H/Y = w/N$. Now note that Y is closely related to the YoLY. If a couple's income derives from l years of effective work then Y=l*YoLY.

$$\frac{H}{YoLY} = \frac{lw}{N}$$ 11* MERGEFORMAT ()

This is like the relationship plotted in Figure 3, with human capital measured in YoLY plotted against the TFR. In logarithmic form, with a coefficient β =-1 on ln(N), this becomes:

$$\ln\left(\frac{H}{YoLY}\right) = \ln(lw) + \beta\ln(N)$$ 22* MERGEFORMAT ()

Lee and Mason (2010) estimated β = -1.05, which was not significantly different than -1.0, consistent with the pedagogical model and the interpretation that we are simply estimating the quantity-quality budget constraint.

Now suppose that w is a function of income level, and specifically $w = \alpha Y^{\gamma}$ or $w = \alpha (YoLY)^{\gamma} l^{\gamma}$. We can write the equation in log form, substituting single coefficients for groups of constants:

$$\ln\left(\frac{H}{YoLY}\right) = \phi + \gamma\ln(YoLY) + \beta\ln(N)$$ 33* MERGEFORMAT ()

The fixed *w* assumption corresponds to $\gamma = 1$ and the assumption that quantity times quality is a constant equal to *wY* corresponds to $\beta = 1$. This is the equation we will estimate below, separately for public and private human capital expenditures. There is no particular reason why γ should be 1 and *w* should be fixed. But if β does not equal 1, then we cannot interpret this equation as estimating the quantity-quality budget constraint.

For the quantity-quality model, it is really surviving children that matters rather than births per se, at least to the extent that variations in child mortality are largely outside the control of the family. In the contemporary setting, child survival is high enough in most countries that it probably makes little difference for the estimates whether we use the TFR or use a measure which reflects survival for children, such as the child dependency ratio (CDR). Since we will be using our estimated equation to backcast to the 1950s for countries that at that time had high mortality, such as China with an infant mortality rate of 195 per thousand in 1950-55, we will also estimate an equation that uses the child dependency ratio.

Results

The results are obtained by regressing the natural log of human capital spending on the YoLY, TFR (Table 2) or the CDR (Table 3), and a European dummy variable equal to 1 for continental European countries. Human capital spending is the synthetic cohort measure described above. (In the simulation model presented below this is represented by hki_sc.) The CDR is computed as the population 0-24 over the population 25 to 59, based on typical cross-over points in consumption and labor income in the NTA data. The dummy variable for Europe is included to capture differences in public policy between social welfare states found in Europe and other high income countries (Australia, Canada, Japan, United Kingdom, and the United States). NTA data are available in the local currency of each country. These values have been converted to US dollars using GDP purchasing power parity factors from World Development Indicators.

Table 2. Correlates of natural log of human capital spending in 39 countries, TFR estimates, YoLY based on GDP purchasing power parity.

	(1) Human capital, public	(2) Human capital, private	(3) Human capital, combined
ln YoLY	1.292***	0.900***	1.185***
	(0.0974)	(0.121)	(0.0473)
Europe	0.130	-1.466***	-0.136
	(0.192)	(0.240)	(0.0934)
ln TFR	-0.631**	-0.765**	-0.480***
	(0.222)	(0.277)	(0.108)
Constant	-1.537	1.632	-0.133
	(1.012)	(1.261)	(0.491)
N	39	39	39

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Public, private, and combined spending on human capital increase with income. Public and combined spending have income elasticities significantly greater than unity, while private spending is insignificantly different than unity. Given fertility or the child dependency ratio, human capital spending rises more rapidly than income across the countries in our data.

Neither public nor combined human capital spending in Europe is significantly different than that found in other countries. Private spending, however, is substantially lower in continental European countries.

The quantity-quality tradeoff is present in both the public and private spending data. The point estimate for the private spending elasticity is somewhat higher than the point estimate for the public spending elasticity using either TFR or CDR, but the difference is not statistically significant.

Table 3. Correlates of natural log of human capital spending in 39 countries, CDR estimates, YoLY based on GDP purchasing power parity.

	(1) Human capital, public	(2) Human capital, private	(3) Human capital, combined
ln YoLY	1.226***	0.864***	1.132***
	(0.122)	(0.156)	(0.0606)
Europe	0.0535	-1.528***	-0.196
	(0.204)	(0.260)	(0.101)
ln CDR	-0.789*	-0.814*	-0.606***
	(0.308)	(0.393)	(0.153)
Constant	-1.450	1.329	-0.0513
	(1.111)	(1.417)	(0.551)
N	39	39	39

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

These results are robust. We have estimated the model using consumption deflator with no effect of note on the results. We have also included the old age support ratio in the model, but in no statistical analysis does it have a statistically significant effect on any of the outcome measures.

Table 4. Correlates of natural log of education spending in 39 countries, TFR specification, YoLY based on GDP purchasing power parity.

	(1) Education, public	(2) Education, private	(3) Education, combined
ln YoLY	1.277***	0.817***	1.150***
	(0.0986)	(0.161)	(0.0510)
Europe	0.144	-1.623***	-0.124
	(0.195)	(0.318)	(0.101)
ln TFR	-0.695**	-1.105**	-0.622***
	(0.225)	(0.368)	(0.116)
Constant	-1.526	2.408	0.106
	(1.024)	(1.675)	(0.530)
N	39	39	39

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We have estimated the model separately for health and education. The results for education spending, reported in Tables 4 and 5, are very similar to those reported for combined human capital spending. The demographic effects appear to be stronger for education than for general human capital. The point estimate of the elasticity for private spending on education is particularly large at -1.1 for the TFR and -1.2 for the CDR.

Table 5. Correlates of natural log of education spending in 39 countries, CDR specification, YoLY based on GDP purchasing power parity.

	(1) Education, public	(2) Education, private	(3) Education, combined
ln YoLY	1.200***	0.758***	1.081***
	(0.124)	(0.208)	(0.0662)
Europe	0.0573	-1.717***	-0.202
	(0.206)	(0.347)	(0.110)
ln CDR	-0.882**	-1.194*	-0.789***
	(0.311)	(0.524)	(0.167)
Constant	-1.392	2.025	0.224
	(1.124)	(1.891)	(0.602)
N	39	39	39

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results for health spending are reported in Tables 6 and 7. The estimated income effects are, again, very similar to those found for education and for combined human capital spending. Private health spending is estimated at being lower in Europe than elsewhere, although the coefficient is not

Table 6. Correlates of natural log of health spending in 39 countries, TFR specification, YoLY based on GDP purchasing power parity.

	(1) Health, public	(2) Health, private	(3) Health, combined
ln YoLY	1.408***	0.896***	1.298***
	(0.139)	(0.224)	(0.0939)
Europe	0.114	-0.813	-0.160
	(0.274)	(0.443)	(0.185)
ln TFR	-0.226	-0.194	-0.00330
	(0.317)	(0.511)	(0.214)
Constant	-4.837**	-0.721	-3.377**

	(1.444)	(2.331)	(0.976)
N	39	39	39

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

statistically significant at the 5% level. The estimated fertility and CDR elasticities are smaller for health than for education and they are not statistically significant. The estimated elasticities are about -0.2 for both public and private (-0.1 in the case of private health in the CDR specification), but the standard errors are quite large.

Table 7. Correlates of natural log of health spending in 39 countries, CDR specification, YoLY based on GDP purchasing power parity.

	(1) Health, public	(2) Health, private	(3) Health, combined
ln YoLY	1.405***	0.919**	1.295***
	(0.172)	(0.277)	(0.116)
Europe	0.101	-0.807	-0.162
	(0.287)	(0.462)	(0.193)
ln CDR	-0.215	-0.106	-0.0104
	(0.433)	(0.698)	(0.292)
Constant	-5.000**	-1.086	-3.359**
	(1.563)	(2.518)	(1.052)
N	39	39	39

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In our view, the statistical analysis is consistent with two important conclusions. The first is that the increased reliance on public investment in human capital that occurs with development is related to income per se (or correlates of income). It is not because public spending responds more to fertility decline than does private spending; it does not. The second conclusion is that the quantity-quality tradeoff is both a public and a private sector phenomenon. Becker’s model was intended to explain private decision-making about fertility and spending on children. As an empirical matter, however, the quantity-quality tradeoff characterizes public spending, as well. In contrast to our earlier results (Lee and Mason, 2010), the analyses with this larger set of countries and including income as a regressor yield estimated elasticities for human capital, education, and health in relation to fertility or surviving children that are significantly less than unity (in absolute value), except for those in Table 5 for spending on education in relation to the child dependency ratio. The general result means that we cannot interpret these estimates as simple descriptions of the multiplicative budget constraint in the quantity-quality model, but they provide an empirical basis for the simulation analysis presented below.

Does fertility decline cause higher investment per child in human capital?

We have estimated equations that describe associations among the TFR or child dependency ratio, human capital investment per child, and various measures of per capita income, for 39 countries in a recent year. However, just because the equations fit the patterns of actual observed differences across countries reasonably well does not mean that they can also tell us what would happen if we exogenously changed fertility through a policy intervention such as a family planning program. The observed patterns arise in part from fertility decline due to family planning programs and in part from fertility decline induced by socioeconomic change including the price and availability of public education, changing female education and employment opportunities, declining mortality, and so on. The United Nations medium fertility projection surely also reflects implicit assumptions about all these factors, and for this reason our estimated association of fertility, education, and income provides a reasonable basis for projecting changes in human capital investments per child.

Now consider the United Nations low fertility projection. In practice this lower trajectory could result from differences in socioeconomic development or from intensified family planning program inputs or both. Socioeconomic changes could include intensified investment in female education as well as general increases in public and private human capital investment. Given this mixture of influences, the estimated equations might provide a reasonable basis for projecting educational attainment for the low fertility scenario as well. But if the United Nations low fertility projection is interpreted as a policy target to be achieved by improved and expanded family planning programs then the situation is different, and requires further consideration.

In an excellent review article, Miller and Babiarz (2014) discuss the causal effects of family planning programs on fertility and also assess the causal effects of family planning programs on educational attainment: “However, long-term studies of socio-economic outcomes suggest that family planning programs may raise educational attainment among women (by 1%-30%) and among children (by 5-18%). Although socio-economic effects at the bottom end of these ranges may seem small, we note that they are not dissimilar in magnitude to gains associated with programs explicitly aiming to boost educational attainment.” (pp. 11-12). These results are drawn from the well-known Matlab Experiment in Bangladesh, for which socioeconomic outcomes have been analyzed by Joshi and Schultz (2013). Combining this reported outcome with causal estimates of the induced fertility decline in Matlab we calculate a range of causal elasticities of educational attainment with respect to fertility from -.73 to -1.34. Our preferred estimates, reported earlier, are close to the smaller (in absolute value) of these. Our measure of human capital investment is quite different than grade attainment, and our estimates differ in other important ways as well.

Overall, we conclude that there is great uncertainty about this matter, but that our estimated equations provide a reasonable basis for estimating the human capital investments along the United Nations low fertility trajectory as well as the medium one. In the simulations to be reported below, we use our own estimated equation.

Conceptual macro framework

The conceptual foundations of the simulation model, presented in detail below, draws on our own previous work on the first and second dividends (Mason and Lee 2007) and Mankiw, Romer, and Weil's (1992) incorporation of human and physical capital into the neo-classical growth framework. Consumption per capita (C/N), used as an indicator of welfare, is governed by a simple identity (the time index is suppressed):

$$\frac{C}{N} = \frac{L}{N} \times (1-s) \times \frac{Y}{L}$$ 44* MERGEFORMAT ()

The first dividend refers to the effect on per capita consumption of changes in population age structure that operates through the support ratio, L/N. The second dividend refers to effects that operate through net production per worker (1-s)Y/L. By net production we mean the output produced per worker that is consumed rather than saved and invested. The association of fertility decline with female labor supply, explored by Bloom, Canning et al. (2009) could also be included here, but we do not address it in this paper.

Support ratio

The number of effective workers, L(t), depends on the exogenously determined population at each age *x* in year t, N(x,t), and a fixed age-profile, l(x), that captures age-specific variation in labor force participation, hours worked, unemployment, and the influences of age on productivity, both positive and negative. (Note that unlike our earlier analysis l(x) is based on the per capita age profile of labor income purged of the effects of age-specific variation in human capital.) The effective labor force is:

$$L(t) = \sum_x l(x) N(x,t)$$ 55* MERGEFORMAT ()

The support ratio is defined as the number of effective workers (L) per person (N).

Net production per worker

The second dividend operates through two channels, investment in physical capital and in human capital. The contributions to output (Y) of both forms of capital are captured using the MRW production function:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} \left(A(t)L(t) \right)^{1-\alpha-\beta}$$ 66* MERGEFORMAT ()

Where K is capital, H is human capital, and A is the level of labor-augmenting technology. The rate of technological growth is exogenous and constant:

$$A(t) = A(0)^{(1+\lambda)t}$$ 77* MERGEFORMAT ()

Output per worker is given by:

$$\frac{Y(t)}{L(t)} = \left(\frac{K(t)}{L(t)} \right)^{\alpha} \left(\frac{H(t)}{L(t)} \right)^{\beta} A(t)^{1-\alpha-\beta}$$ 88* MERGEFORMAT ()

Or equivalently by:

$$\frac{Y(t)}{L(t)} = k(t)^{\frac{\alpha}{1-\alpha-\beta}} h(t)^{\frac{\beta}{1-\alpha-\beta}} A(t)$$ 99* MERGEFORMAT ()

where k is the capital-output ratio (K/Y) and h is the human capital-output ratio (H/Y).

Effective labor is exogenously determined (see equation Error: Reference source not found).

The relationship between saving and the capital-output ratio is given by:

$$\dot{k} = s_k - (g + \delta_k)k$$ 1010* MERGEFORMAT ()

where $\dot{k} = \partial k / \partial t$, s_k is investment in physical capital as a share of GDP, *g* is the rate of growth of GDP, and δ_k is the constant capital depreciation rate, and time is suppressed for notational simplicity.

A similar expression applies to spending on human capital and the human capital-output ratio:

$$\dot{h} = s_h - (g + \delta_h)h$$ 1111* MERGEFORMAT ()

where $\dot{h} = \partial h / \partial t$, s_h is investment in human capital as a share of GDP, *g* is the rate of growth of GDP, and δ_h is the human capital depreciation rate.

In steady state, we have $\dot{k} = \dot{h} = 0$ and $g = \lambda + n$ the rate of growth of technological progress plus the rate of growth of the effective labor force or, equivalently, the rate of growth of the population. In equilibrium, we have:

$$s_k = (\lambda + n + \delta_k)k$$ 1212* MERGEFORMAT ()

$$s_h = (\lambda + n + \delta_h)h$$ 1313* MERGEFORMAT ()

Equations Error: Reference source not found and Error: Reference source not found are social budget constraints that govern the tradeoff between saving and capital. At a lower population growth rate, n, the saving rate necessary to maintain a given capital-output ratio is lower. The same is true for human capital. The social budget constraints arise purely from growth dynamics and involve no assumptions about behavior or policy.

Steady state results

Steady state results are easily obtained for two polar cases that differ in their assumptions about “behavior”.

Solow case

In the Solow case, saving rates are exogenous. The equilibrium capital-output and human capital-output ratios are given by:

$$k^e = s_k / (\lambda + n + \delta_k)$$ 1414* MERGEFORMAT ()

$$h^e = s_h / (\lambda + n + \delta_h)$$ 1515* MERGEFORMAT ()

Net production per worker, production excluding investment, is given by:

$$(1 - s)\frac{Y}{L} = (1 - s_k - s_h)\left(\frac{s_k}{\lambda + n + \delta_k}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{s_h}{\lambda + n + \delta_h}\right)^{\frac{\beta}{1-\alpha-\beta}} A(t)$$ 1616*

MERGEFORMAT ()

From inspection a decrease in the population growth rate leads to higher net production per worker. Given saving rates, an decrease in the population growth rate leads to capital deepening and human capital deepening, here measured by capital-output and human capital-output ratios. This is the standard Solow result as extended to include human capital in Mankiw, Romer, and Weil (1992) (MRW). To summarize: if saving rates are exogenous, a decline in the population growth rate leads to a second dividend in the long run.

Fixed capital-output case

In this case the capital-output and human capital-output ratios are exogenous while the saving rates are endogenous (Lee, Mason et al. 2014). Net production per worker in equilibrium is given by:

$$(1-s)\frac{Y}{L} = \left(1-(\lambda+n+\delta_k)k-(\lambda+n+\delta_h)h\right)k^{\frac{\alpha}{1-\alpha-\beta}}h^{\frac{\beta}{1-\alpha-\beta}}A(t)$$

1717* MERGEFORMAT ()

Again by inspection, we see that a decrease in population growth leads to an increase in net production, with the effect operating through the saving rates for physical and human capital. Slower population growth yields a long-run second dividend in this case, as well.

Human capital dynamics

The MRW formulation provides an intuitive and useful approach by treating human and physical capital dynamics in parallel fashion. Important features of human capital dynamics are captured in more recent studies that recognize that human capital is embodied (Ashraf al. 2013 or Crespo Cuaresma et al. 2014). Human capital only influences GDP, as we measure it, only when those who are the recipients of human capital spending are employed. This has implications for human capital saving and depreciation. First, the process of creating human capital is characterized by a substantial lag. Years may pass between the time children receive spending on health or education and they become workers. In the formulation presented above (equations (4) or (16), for example) human capital saving is measured as current spending on the education and health of children. In equation (11) human capital saving occurs when the recipient of human capital becomes of member of the workforce. Of course, some will never enter the labor force. Second, human capital depreciates as workers leave the workforce. One could calculate a depreciation rate based on the useful life of that human capital as is often done for traditional forms of capital. Or one can calculate depreciation based on simulated withdrawal from the labor force with depreciation endogenous depending on population age structure as it influences the share of the workforce at the end of its “useful life”. The detailed simulation model presented below reflects the more complex and interesting dynamics that arise when we recognize the embodied nature of human capital.

Simulation model

Key elements of the simulation model are governed by the conceptual framework described above. Per capita consumption is determined by the support ratio (the first dividend) and net production (the second dividend) as shown in equation 4.

The support ratio is the ratio of the effective labor force to population. The effective labor force, as defined by equation 5, is the number of workers adjusted to incorporate age variation in labor force participation, unemployment, hours worked, and experience on productivity. In this formulation, the effective labor force does not reflect the influence of human capital investment, which is included in our measure of human capital. See the appendix for a detailed explanation of the method.

Net production is the portion of output that is consumed rather than saved. Saving is broadly defined to include both conventional saving as defined in national accounts, for example, and human capital spending. Output is based on the MRW production function with three factors of production, capital, human capital, and labor (equation 6). The behavioral mechanisms that determine saving and Investment in physical capital are of secondary interest and we assume that the capital-output ratio is fixed. Saving, or equivalently investment, in physical capital is given by:

$$s_k(t) = (g(t) + \delta_k)k$$

1818* MERGEFORMAT ()

where k is exogenous and time-invariant. We rely on this case because we believe it is broadly consistent with two important empirical features of saving and capital. The first is that the capital-output ratio has been relatively constant over extended periods of time in many countries (see references in Lee, Mason et al. (2014)) and certainly more so than the saving rate. The second is the strong positive correlation between the saving rate and the rate of GDP growth, known as the rate of growth effect, found in many studies (Modigliani and Brumberg 1954; Mason 1987; Mason 1988). We note, however, that there is some evidence that capital-output ratios have increased recently in high-income countries (Piketty 2014).

Human capital saving is simulated using regression results reported above to project synthetic cohort values (*hki_sc(t)*). Synthetic cohort values of human capital investment are determined by the child dependency ratio and the average of the per capita labor income (yl(x,t)) of adults age 30-49, YoLY(t):

$$\begin{aligned}
\ln hki_sc(t) &= \phi + \gamma \ln YoLY(t) + \beta \ln CDR(t) \\
YoLY(t) &= \sum_{x=30}^{49} yl(x,t) \\
CDR(t) &= \sum_{x=0}^{24} N(x,t) \Big/ \sum_{x=25}^{59} N(x,t)
\end{aligned}$$

1919* MERGEFORMAT ()

We then map from synthetic cohort values to human capital investment by single year of age x using model age-profiles constructed from NTA data (see appendix).

Human capital is endogenous, cohort specific, and based on public and private spending on health and education during the childhood ages (3-26 for education and 0-17 for health). Human capita spending contributes to the production of output, however, only to the extent that those who possess it are employed. This implies a considerable lag between the time at which human capital investment is made and human capital is realized. Moreover, human capital declines in value as workers withdraw from the labor force, experience unemployment, or reduce their hours. For fully employed workers, human capital may appreciate in value as workers gain experience and depreciate in value as workers are subject to decline in their cognitive abilities and other productivity-impairing effects of aging. These effects are incorporated into the analysis using the age-profile of productivity, l(x).

The method for calculating human capital differs from the approach taken in MRW. The human capital per person of age x in year t, h(x,t), is equal to the cumulative investment in human capital per person, and the effectiveness with which those at that age are engaged in GDP-producing activities:

$$h(x,t) = \begin{cases} l(x)\sum_{z=0}^{26} hki(z,t-x+z) \text{ for } x>26 \\ l(x)\sum_{z=0}^{x} hki(z,t-x+z) \text{ for } x\leq 26. \end{cases}$$

2020* MERGEFORMAT ()

Total human capital in period t is calculated by multiplying by the population of each age and summing across age. Dividing by total output yields the human capital intensity of the economy, h(t):

$$h(t) = \sum_x h(x,t)N(x,t) \big/ Y(t).$$

2121* MERGEFORMAT ()

Estimating h(x,t) requires historical estimates of age-specific human capital spending. These are constructed using methods reported in the appendix.

Model parameters and initial conditions

The purpose of these simulations is to assess the economic implications of a wide range of possible demographic outcomes as a poor country experiences its fertility transition. The analysis is not intended to provide forecasts or projections for any particular country. The economic model that we employ is generic and the model parameters (Table 8) and the initial conditions (Table 9) are not based on any particular country.

Table 8. Model parameters

Variable	Value	Notes
Age-profile of effective labor	See appendix	

(l(x))		
Elasticity of output with respect to capital and human capital	1/3, 1/3	Estimates from Mankiw, Romer, and Weil (MRW).
Rate of technological progress (λ)	0.02	Standard assumption.
Depreciation rate, capital (δ_k)	0.05	Standard, e.g., MRW.
Depreciation rate, human capital (δ_h)	Endogenous	See text
Human capital investment parameters (ϕ, γ, β)	See estimates in Table 3.	Public and private human capital spending computed separately and then combined.

We consider a country that has not yet begun its demographic transition and is very poor (Table 9). Demographic conditions are based on UN estimates for Nigeria in 1950, which had a total fertility rate of 6.4 births per woman. The support ratio was 0.34 effective workers per person and the child dependency ratio (the number under 25 to those 25-59) was 1.8. The population growth rate was moderately high at 1.5% because death rates were quite high in 1950.

Income per effective worker is set to $250 and, based on the model, per capita income is $129 and per capita consumption just over $100. The capital-output ratio is fixed at 2, by assumption, and hence capital per worker is $500. The initial human capital-output ratio and human capital per worker, constructed using historical data, are equal to 0.97 and $364, respectively. The initial investment and human capital investment rates are 14% and 7.9% of total output, respectively, but investment rates net of depreciation are much smaller at 4% and 0.9%, respectively.

Table 9. Initial conditions, poor, pre-transition country, 1950

Total fertility rate	6.4	Support ratio	0.34
Population growth rate (%)	1.5	Child dependency ratio	1.8
Income per effective worker	$250	Per capita consumption	$101
Capital-output ratio	2.0	Human capital-output ratio	0.97
Capital per effective worker	$500	Human capital per effective worker	$364
Investment rate	0.140	Human capital investment rate	0.079

From 1950 to 2010, all scenarios are based on population and fertility estimates for Nigeria. Thereafter, we use three demographic scenarios to simulate the economy and to assess the first and second demographic dividends. The medium scenario uses the medium fertility scenario projection for Nigeria from World Population Prospects 2012 (United Nations Population Division 2013). This scenario anticipates a steady but gradual decline in fertility with replacement fertility reached near the end of this century. The low fertility scenario, also based on the UN projections, assumes that fertility will be lower by one-half child. Under these conditions replacement fertility would be realized around 2075. The third scenario is based on radical fertility decline. This scenario was constructed assuming fertility decline as rapid as experienced by China during its fertility transition. Under this scenario, the total fertility rate drops from 6 births per woman in 2010-15 to replacement in only twenty-five years. The TFR reaches a low of about 1.5 births per woman in 2045. Thereafter, the TFR rises gradually to reach

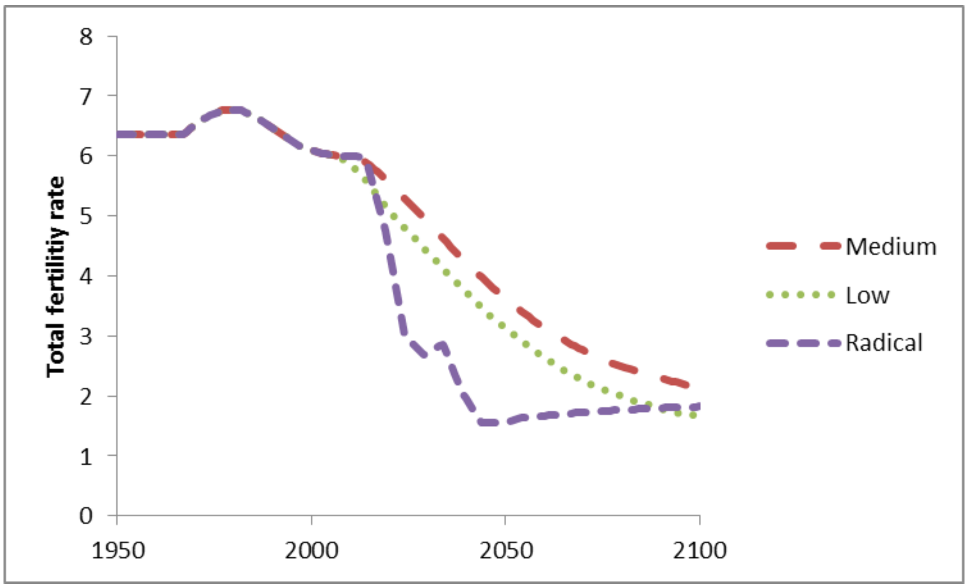

Figure 4. Total fertility rate, 1950-2100, under three fertility scenarios.

1.8 births per woman toward the end of the simulation (Figure 4). Mortality and migration assumptions are the same in all three scenarios.

Fertility decline leads to an immediate decline in the child dependency ratio (CDR) and an immediate increase in the support ratio as shown in Figure 5. From the pre-transition peak of over 2 child dependents per prime-age adult, the CDR drops in 2050 to 1.5 or 1.35 for the medium and low fertility scenarios to a very low 0.75 for the radical decline scenario. The support ratio rises from a low of 0.31 effective workers per person in 2010 to 0.37, .40, and .54 for the three scenarios. The rise in the support ratio leads to the first demographic dividend presented below.

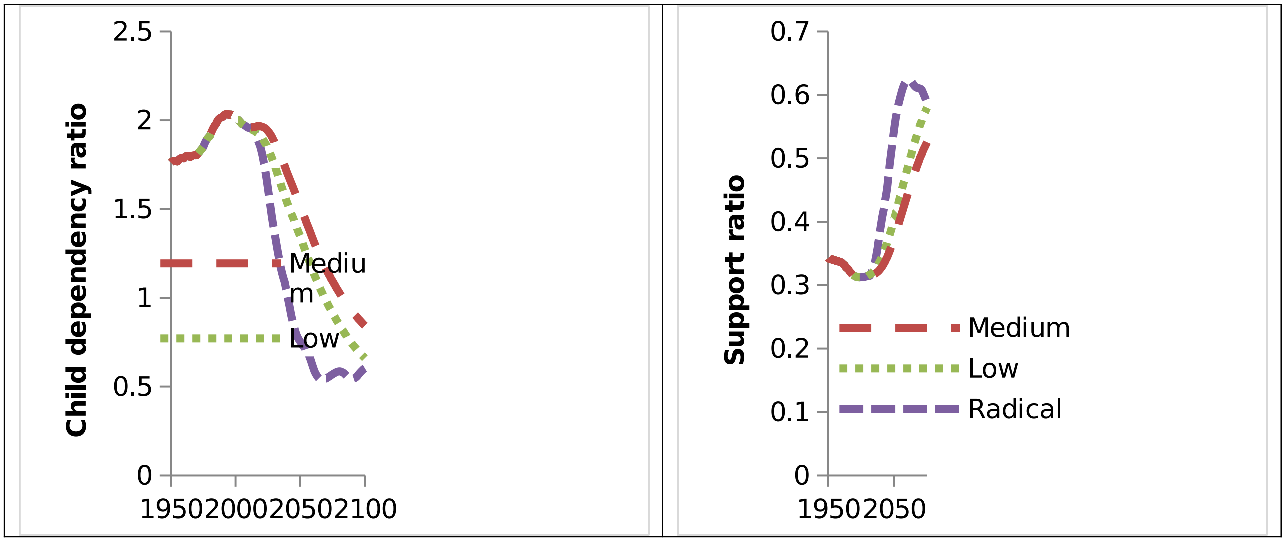

Figure 5. Child dependency ratio (left) and support ratio (right), three fertility scenarios. The child dependency ratio (CDR) is defined as the population under 25 relative to the population 25-59. For the definition of the support ratio see the text.

Pre-transition and the medium fertility scenario

We begin by considering both the prolonged period of high fertility from 1950 to 2010 followed by the medium scenario fertility transition. The simulated rates of growth of population, income, per capita income, and per capita consumption are reported in Table 10. High birth rates combined with lower death rates lead to population growth rates exceeding 2.5 percent per year for 1975 -2050. Population growth drops slowly thereafter reaching about 1 percent per year for 2075-2100.

Table 10. Annual growth rates (percent), poor, slow transition

	Population	Income	Per capita income	Per capita consumption
1950-1975	2.1	3.3	1.2	1.0
1975-2000	2.7	3.8	1.1	1.1
2000-2025	2.7	4.4	1.6	1.6
2025-2050	2.5	4.9	2.4	2.4
2050-2075	1.8	4.9	3.0	3.1
2075-2100	1.1	4.2	3.0	3.2

Rapid population growth leads to rapid growth in the effective labor force and total output. Per capita income and per capita consumption grow quite slowly during the pre-fertility transition period – only about one percent per year. Growth is more rapid once the fertility transition begins. The growth rates of per capita income and per capita consumption rise steadily until they reach 3 percent per year, triple the earlier rate, during the second half of the Twenty-first Century.

Higher growth is realized because of changes in the growth rate of the support ratio (L/N) and the growth rate of net production ((1-s)Y/L) as shown in Figure 6. Prior to the fertility transition the support ratio was a moderate drag on economic growth. For the entire 2000-25 period, growth in the support ratio added about 0.1% per year to growth in per capita consumption. Growth in the support ratio only contributes in a meaningful way to economic growth during the final three twenty-five year period – adding roughly 0.5 percentage points to economic growth. In 2025-50 and 2050-75, growth in the support ratio explains about one-quarter of the economic growth. The support ratio is declining in importance by the end of the simulation, for the last twenty-five year period, growth in the support ratio explains only 17 percent of overall economic growth.

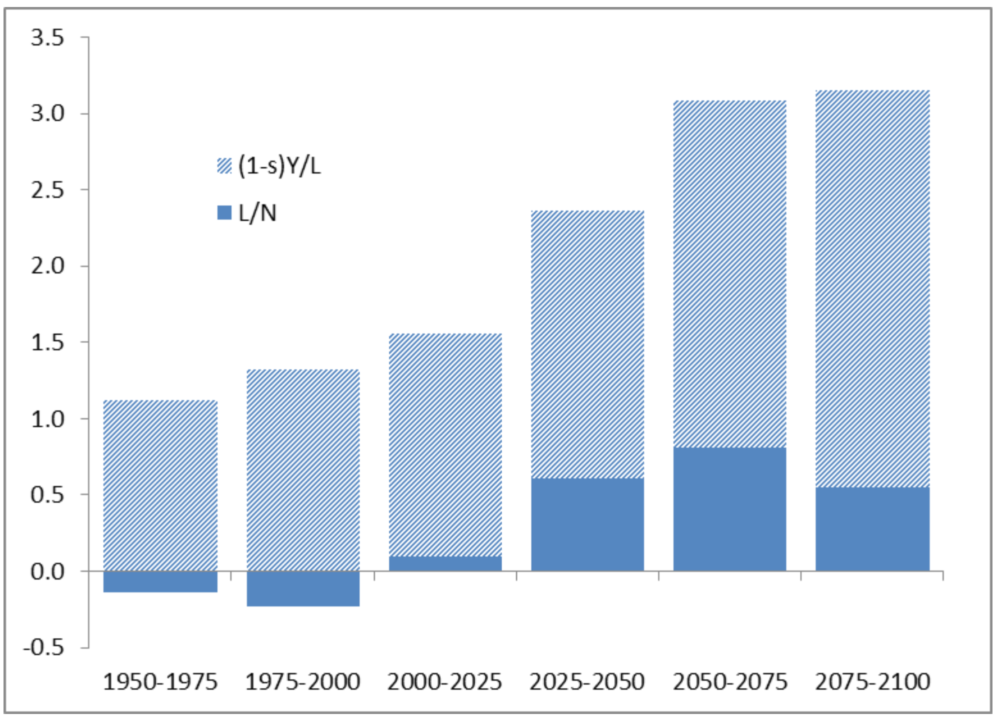

Figure 6. Growth in per capita consumption and its sources: growth in the support ratio (L/N) and growth in net production per worker ((1-s)Y/L). Scenario: Poor, high fertility country with moderate fertility decline beginning in 2010. File: Simulations.Nigeria.CDR.xlsx/Econ summary

The growth in net production is very moderate at little more than one percent per year in the early part of the simulation. It rises steadily, however, and by the latter part of the simulation is growing at roughly 2.5 percent per year. The rise in the growth rate of net production is primarily responsible for the higher rate of economic growth that accompanies the transition to lower fertility.

Growth in net production is due to a variety of factors – technological change, changes in the saving rates, and the accumulation of physical and human capital that occurs throughout the simulation period. The trends in capital and human capital per worker are quite different than the trends in capital and human capital intensity (K/Y and H/Y). By assumption, the capital-output ratio (K/Y) is constant at 2.0 throughout the simulation as shown in Figure 7. Capital grows at the same rate as output, but output grows more rapidly than the effective labor force L. As a consequence, we see a very substantial increase in capital per worker. Between 1950 and 2000, capital per worker almost doubles – increasing from $750 to $1480. During the next 50 years, capital per worker more than doubles reaching $3300. During the final 50 years, capital per worker more than triples passing $10,000 per worker.

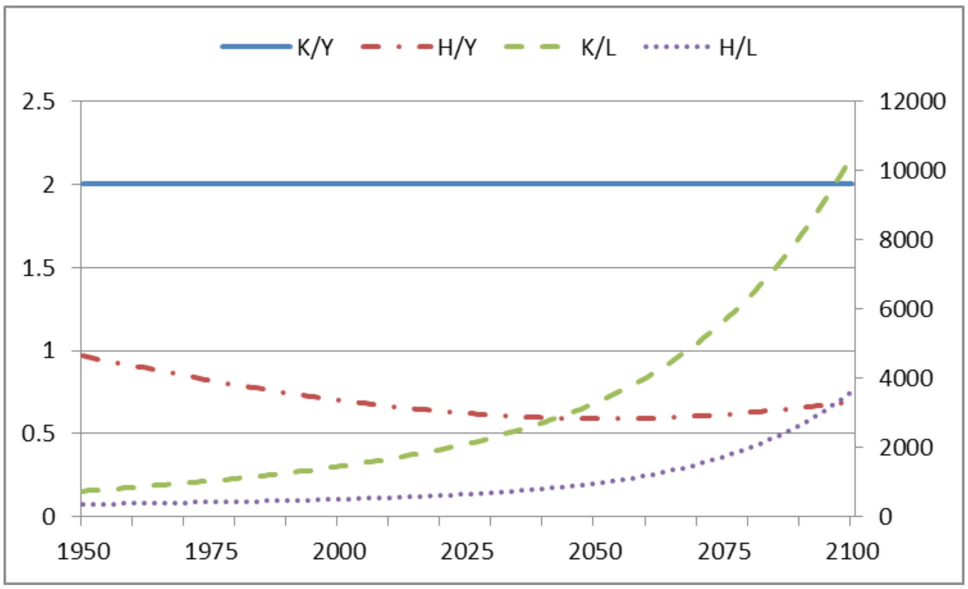

Figure 7. Trends in capital and human capital, 1950 to 2100. Scenario: Poor, high fertility country with moderate fertility decline beginning in 2010. File: Simulations.Nigeria.CDR.xlsx

The human capital trend is much less favorable under this scenario. The human capital–output ratio is about 1 in 1950, but it declines to 0.70 in 2000 and less than 0.60 in 2050. It recovers slightly but by 2100 is still only 0.69 – the level of 2000. Human capital per worker grows but much more gradually than physical capital. Human capital increases from $360 in 1950 to $511 in 2000, $970 in 2050, and $3600 in 2100. Over the entire 150 year period, human capital increases by 10-fold as compared with 14-fold increase in physical capital per worker.

Fertility decline and the first and second dividends

The growth in per capita consumption under the medium fertility scenario is a consequence of demographic forces and technological progress, which have both direct and indirect effects through capital and human capital accumulation. The effects of demography on economic growth are in themselves complex. Changes in age structure are the consequence of current and historical trends in fertility and mortality. Consequently, many of the economic effects of changing age structure are built into current conditions. Policies, if effective, can influence fertility, mortality, or immigration and indirectly population age structure in a slow and evolving way.

Our interest here is to assess the magnitude and timing of the first and second dividend that occur because of fertility decline, per se. This question can be answered by comparing the simulation results from each of our scenarios to a counterfactual – the simulated performance of the economy in the absence of fertility decline. For this purpose, we rely on the UN population projection using the constant fertility scenario. In all other respects the assumptions and initial conditions are identical to those employed for the medium scenario, the low fertility scenario, and the radical fertility scenario.

We begin with the bottom line; each of the fertility decline scenarios leads to a substantial increase in per capita consumption growth as compared with the no fertility decline scenario (Figure 8). For the medium and low fertility scenarios, the gains are moderate between 2010 and 2040 averaging 0.4 and 0.6 percentage points of higher annual growth respectively. After 2040 the gains are very large with the medium fertility scenario adding between 1.4 and 1.5 percentage points to growth in per capita consumption and the low fertility scenario adding between 1.6 and 1.7 percentage points to economic growth. The radical fertility decline scenario produces a much more immediate impact with growth higher by 1.4 percentage points between 2010 and 2040 and an even larger impact – 2.3 percentage points over the following three decades.

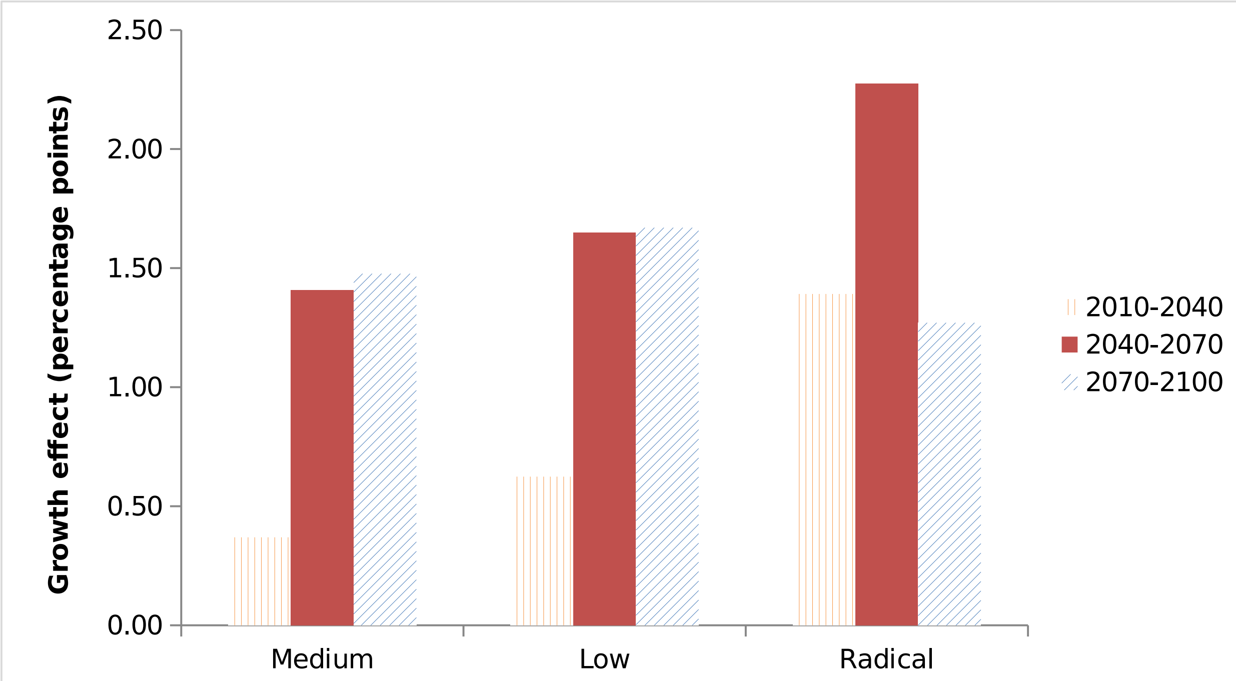

Figure 8. Effect of fertility decline on the annual rate of growth of per capita consumption, 2010-2040, 2040-2070, and 2070-2100; three fertility decline scenarios. File: DD&GJ_AGEBTA_2015_lite version.pptx

The cumulative effect of the demographic dividends can be seen in Figure 9 which shows the percentage increase in per capita consumption as compared with the counterfactual – no fertility decline. By 2040, per capita consumption would be higher by 12 percent given the medium fertility scenario, 22 percent given the low fertility scenario, and 53 percent given the radical fertility decline scenario. The cumulative effects grow ever larger so that by 2070 per capita consumption is higher by 68%, 96%, or 217% for the medium, low, and radical fertility scenarios, respectively. By the end of the simulation, fertility decline results in per capita consumption higher by between 150% and 350% depending on the scenario.

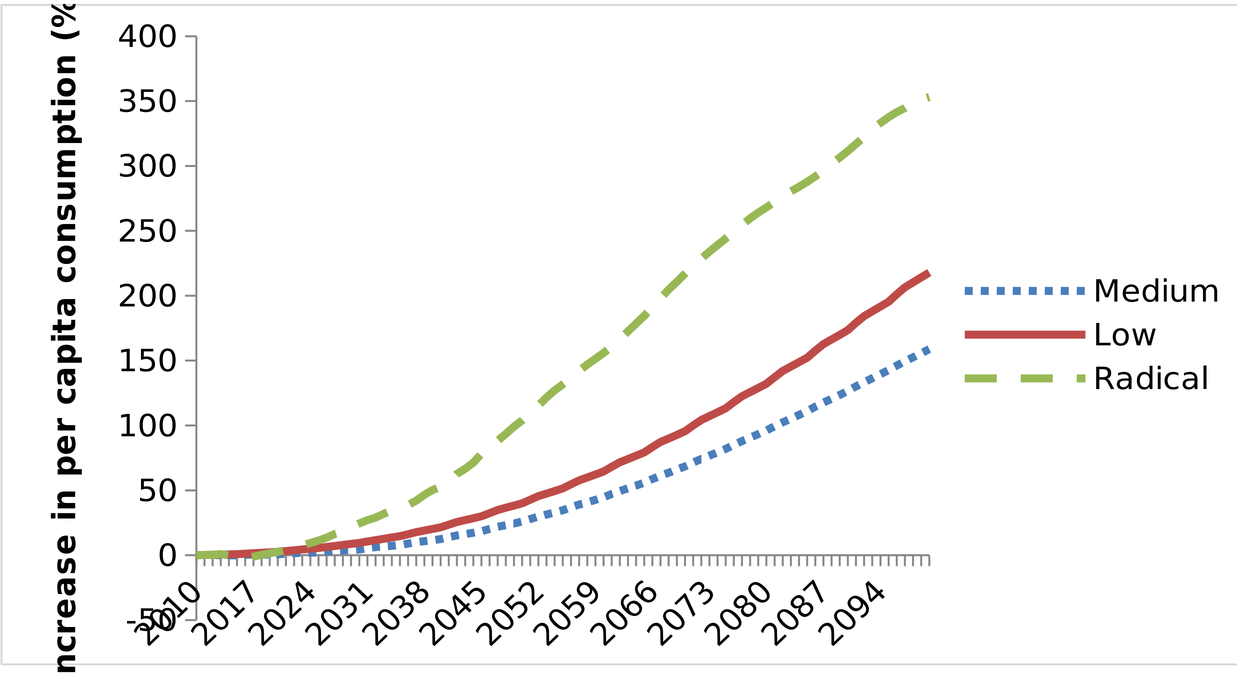

Figure 9. Percentage effect on per capita consumption of demographic dividends, 2010-2100; three fertility scenarios. File: DD&GJ_AGEBTA_2015_lite version.pptx

What accounts for these very substantial gains? We start by separating the additional growth in per capita consumption into the first and second demographic dividend shown in Figure 10. Given the medium and low fertility scenario, the first dividend persists through the remainder of the 21st Century contributing between 0.35 and 0.9 percentage points to growth in per capita consumption. In both scenarios the first dividend's largest effect is in the second thirty year period. The low fertility scenario produces moderately higher first dividends throughout the simulation. The radical fertility scenario produces a first dividend that comes earlier with an impact that is greater but more concentrated. In 2010-2040, the first dividend adds 1.3 percentage points of additional growth and it remains very strong for the 2040-2070 period at 0.85 additional percentage points of growth. Then, the first dividend ends depressing growth by 0.16 percentage points per year between 2070 and 2100.

In all scenarios the second dividend effects are delayed – important only after 2040. They are substantial in all scenarios adding at least 0.5 percentage points to economic growth and, in some cases, much more. The low fertility scenario adds a full percentage point to economic growth for the 2070-2100 period while the radical fertility decline scenarios adds 1.4 percentage points of growth in both the 2040-70 and 2070-2100 periods.

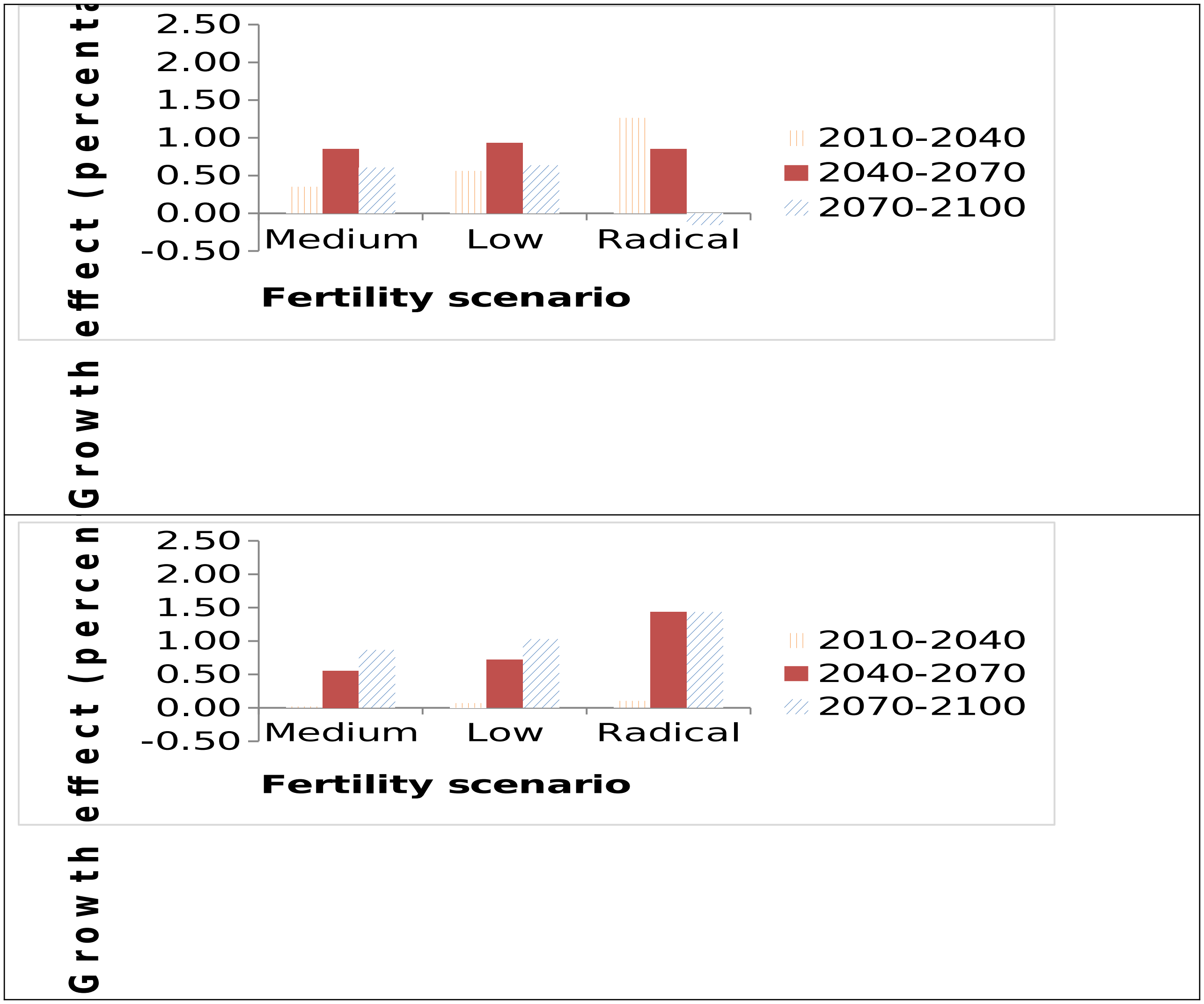

Figure 10. First dividend (upper panel) and second dividend (lower panel) for three fertility scenarios. First dividend is the effect of fertility decline on growth in the support ratio. Second dividend is the effect of fertility decline on growth in net production per worker. File: DD&GJ_AGEBTA_2015_lite version.pptx

What caused the second dividend?

The second dividend can be traced to three sources: a change in the consumption or saving rate, capital deepening and human capital deepening. Growth of net production can be calculated by taking the ln and differentiating with respect to t:

$$(1-s)\frac{Y(t)}{L(t)} = (1-s)\left(\frac{K(t)}{L(t)}\right)^{\alpha}\left(\frac{H(t)}{L(t)}\right)^{\beta} A(t)^{1-\alpha-\beta}$$

$$\frac{\partial}{\partial t}\ln\left((1-s)\frac{Y(t)}{L(t)}\right) = \frac{\partial}{\partial t}\ln(1-s) + \alpha\frac{\partial}{\partial t}\ln\left(\frac{K(t)}{L(t)}\right) + \beta\frac{\partial}{\partial t}\ln\left(\frac{H(t)}{L(t)}\right) + (1-\alpha-\beta)\frac{\partial}{\partial t}\ln(A(t))$$

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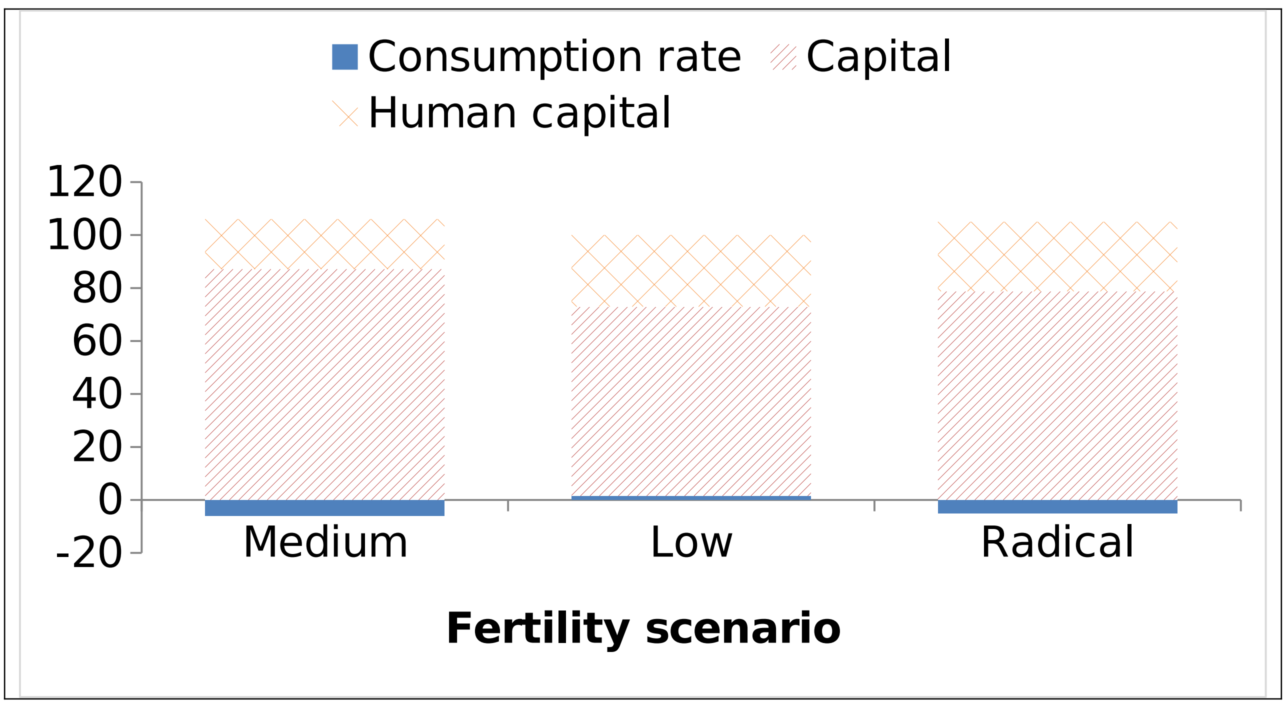
The same calculation can be applied to the counterfactual scenario (no fertility decline). Taking the difference yields the additional growth in net production over the counterfactual scenario as consisting of three terms. Using a delta to represent the difference between a scenario and a counterfactual we have:

$$\Delta \frac{\partial}{\partial t} \ln\left((1-s)\frac{Y(t)}{L(t)} \right) = \Delta \frac{\partial}{\partial t} \ln(1-s) + \alpha\Delta \frac{\partial}{\partial t} \ln\left(\frac{K(t)}{L(t)} \right) + \beta\Delta \frac{\partial}{\partial t} \ln\left(\frac{H(t)}{L(t)} \right)$$ 2323* MERGEFORMAT ()

The second dividend is due to changes in the rates of growth of three factors –the consumption rate (1-s), capital per effective worker, and human capital per effective worker.

The results are reported in Figure 11 for two periods 2010-2040 and 2040-2070. The results for 2070-2100 are very similar to those for 2040-2070. The relative importance of the second dividend channels differs little across the scenarios. For the initial thirty year period, the main contributor to the second dividend was capital deepening with human capital playing a secondary role. Keep in mind, however, that the second dividend is relatively modest during this period. The second dividend plays a much more important role after 2040 and the human capital channel is very important



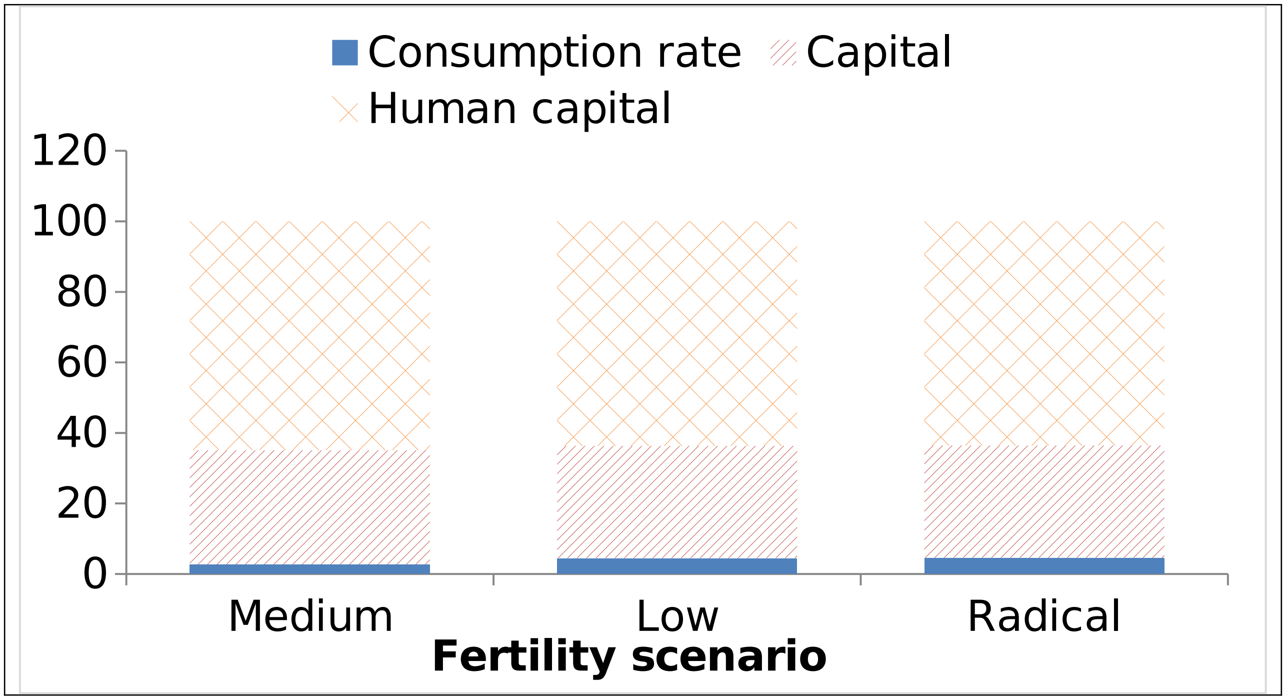


Figure 11. Share of second dividend contributed by an increase in its three components: consumption rate, capital, and human capital; three fertility scenarios. Upper panel reports results for 2010-2040 and lower panel is for 2040-2070. File: DD&GJ_AGEBTA_2015_lite version.pptx

explaining almost two-thirds of the second dividend. Capital deepening explained almost one-third of the second dividend. Changes in the saving rate played a small role in the second dividend. During the first thirty-year period, increases in the saving rate depressed consumption per effective worker. Later, saving rates declined contributing between 3 and 8 percent of the second dividend.

Human capital investment revisited

Human capital investment is a broad, comprehensive measure of resources devoted to the development of children and youth. There are many important questions about the relative contribution to development of public versus private spending on health and human capital, and the ways such spending affects economic inequality in subsequent generations. Surely spending at some ages is more important than spending at others. Spending on neonatal care or primary education may matter more than spending on child health or tertiary education, for example. Another important issue to explore is the potential complementarity between investment in health and education. These are just some of the important issues that could be analyzed in the future given sufficient NTA data, but not at the present.

A simpler and instructive exercise is to identify the changing importance of human capital investment components as a high fertility country experiences demographic change. In Table 11, we report the simulated level and composition of human capital investment expressed in YoLYs for the low fertility scenario. Inevitably they conform to the cross-sectional patterns that we have discussed above.

Over the course of the simulation, average human capital investment per child is projected to increase very substantially. In 2010, the total investment per child was about 1.5 YoLYs. The investment rises gradually during the first thirty years reaching only 1.8 YoLYs by 2040, but accelerates thereafter reaching 2.7 YoLYs by 2070 and almost 4 by 2100 – a level on par with today's advanced economies. Income has little effect on education, expressed in YoLYs, although a YoLY is worth far more in real terms in 2100 than in 2010. The change in human capital is a consequence of the quantity-quality tradeoff. The causal connections are impossible to discern, but clearly the development process is marked by a strong shift towards few children with high investment per child.

An important result is the central role of the public sector in the quantity-quality transition. In 2010, about 38% of spending on human capital investment was public and 62% private. The public share rises steadily over the simulation exceeding half of the total by 2100. All of that gain is due to public education spending. Public health investment remains at about 5% of the total throughout the simulation. Private health spending drops substantially as a share of the total between 2010 and 2100. In YolYs, private spending on health is flat over the entire simulation. Private education as a share of the total drops significantly over the simulation, particularly during the middle thirty year period.   Private education spending per child in YoLYs is rising over the entire simulation, but substantially more slowly than public sector spending.

Table 11. Human capital spending and composition, synthetic cohort values, low fertility scenario.

	Human capital spending (YoLY)	Composition of human capital spending (%)			
		Public education	Private education	Public health	Private health
2010	1.49	32.8	49.4	5.1	12.7
2040	1.82	36.6	47.8	5.4	10.2
2070	2.72	41.4	46.7	5.1	6.8
2100	3.94	47.2	42.9	5.3	4.6

The public-private split has many important implications to be explored. It shows clearly how important public policy is to realizing the second demographic dividend. The economic gains identified here depend directly on the public sector directing greater resources into human capital investment. The results have potentially interesting implications for inequality to the extent that public investment in education and health is broadly distributed across all socio-economic strata, whereas private spending has a steep socioeconomic gradient.

Comparison to a similar study

An excellent paper by Ashraf, Weil and Wilde (2013, henceforth AWW) simulates the effects of fertility decline on per capita income in Nigeria, contrasting the outcomes for the United Nations medium and low scenarios. Our conceptual approach is very similar to theirs, but the emphasis and implementation are somewhat different. In our analysis, we compare outcomes to a baseline scenario in which no fertility decline occurs whereas they are comparing the low and medium scenarios with TFRs that differ by one-half child. Their outcome variable of interest is income per capita, while ours is consumption per capita, where human capital expenditures are treated as a form of saving and excluded from consumption. In AWW consumption is a constant share of income, while in our paper when fertility declines, consumption rises as a share of income since less needs to be invested to keep the capital-income ratio constant, but at the same time expenditures on human capital rise, reducing consumption as a share of income. AWW relies on microeconomic estimates in the literature for their parameter values in the simulation while we use macroeconomic data from NTA to estimate cross-national relationships and for the age profiles of labor income and consumption that we use to calculate changing dependency.

AWW discusses many potential economic effects of fertility decline, but from among all those actually included in their simulation, our analysis incorporates all but two. The first is their inclusion of land as a factor of production and the second is increasing female labor force participation in response to declining fertility. In their evaluation of results both these factors play minor roles. Our analysis includes per capita income growth as a driver of increased human capital investment per child in addition to declining fertility, which intensifies all the other included effects. In addition to these differences, there are also differences in functional form.

The base year is 2010 for both studies, and it is possible to compare the two sets of results after 20 and 50 years, that is for 2030 and 2060. We find that the differences between outcomes for the medium and low fertility trajectories are small. In 2030 AWW find a relative gain in per capita income for low fertility of 5.6% while we find a relative gain of 4.8%. By 2060 this is 11.9% versus 12.7%. If we instead compare the differences for consumption rather than income, in 2030 this is still 5.6% for AWW versus 4.7% for us, and in 2060 11.9% versus 13.4%. The close agreement of these results despite the differences in data, model specification, and parameter estimates, is very encouraging and lends credence to both studies.

There are similarities and differences between the results with respect to the channels of economic growth. An important similarity is that the first dividend (dependency effect in AWW) is particularly important in the early part of simulations while second dividend effects become much more important in the later part of the simulations. The two models differ greatly in that our assessment of the importance of the human capital channel is much greater. This may be due in part to difference specifications of the capital sector, fixed saving in their model versus fixed capital output in our model, and partly due to feedback effects in our model that intensify the contribution of human capital to economic growth. Perhaps most important is that the AWW analysis is intended to quantify the effect of an exogenous change in fertility through human capital on development. Our assessment of the importance of human capital includes the full effects irrespective of the drivers that are leading to lower fertility and high human capital investment.

Conclusion

Low income countries are poor, in part, because per child investment in human capital is so low. This state of affairs is to an extent unavoidable because the resources available for any purpose are quite limited. But the constraints facing families are much greater when they must provide for many children. Low human capital spending per child is a manifestation of the quantity-quality tradeoff postulated by Becker and confirmed by many studies including our own. Although developed with the decision-making of families in mind, the quantity-quality tradeoff is salient for public investment in human capital, as well.

The deep connections between the number of children and investment per child have important implications for understanding how countries achieve economic development. The demographic transition is accompanied by a human capital transition with fundamental shifts in the share of the population in the working ages and the skills and productivity of those workers. Moreover, changing demography influences capital accumulation and the productivity of workers beyond the influences of changes in human capital.

Building on the MRW growth model to incorporate the effects of capital, human capital, and labor, we show that the changes in age structure and human capital investment over the demographic transition have substantial and lasting effects on standards of living. The first dividend, the growth in the relative size of the workforce, provides an important, but temporary, boost to economic growth. The second dividend, capturing the effects of changing investment in human and physical capital, is substantial and long-lasting. Development depends on many factors, but demographic change and the quantity-quality tradeoff figure prominently by our assessment.

These conclusions must be tempered, however, by many qualifications and reservations. One of the most important issues is to improve our measurement of human capital and our understanding of its impact on economic growth. Our measure of human capital is a cost measure – the amount invested in health and education of children and youth. The connections between investment and outcome measures such as educational attainment or cognitive development are not understood. Moreover, our measure of cost could be improved by including the opportunity cost of students and the value of non-market inputs to human capital, such as the time of parents and grandparents.

The analysis presented here does not identify particular causal pathways. In particular, we do not think that the decline in fertility is necessarily the cause of greater human capital investment. Fertility decline and rising human capital investment are mutually reinforcing, but both are influenced by a host of forces including policy.

Appendix

Model schedules of human capital investment

Model profiles are used to calculate spending on human capital by single year of age based on synthetic cohort values of human capital spending (equation Error: Reference source not found) from the regression model. Model profiles are constructed using the normalized values of human capital investment by age. The values are normalized by dividing per capita human capital investment at each age by the labor income of persons 30-49 (YoLY). The profiles have been constructed separately for public human capital investment (Figure A.1) and private human capital investment (Figure A.2) using NTA data for 39 countries. We have sorted the countries into four groups based on the synthetic cohort values, three groups consisting of ten countries and one group consisting of nine countries with the highest synthetic cohort value.

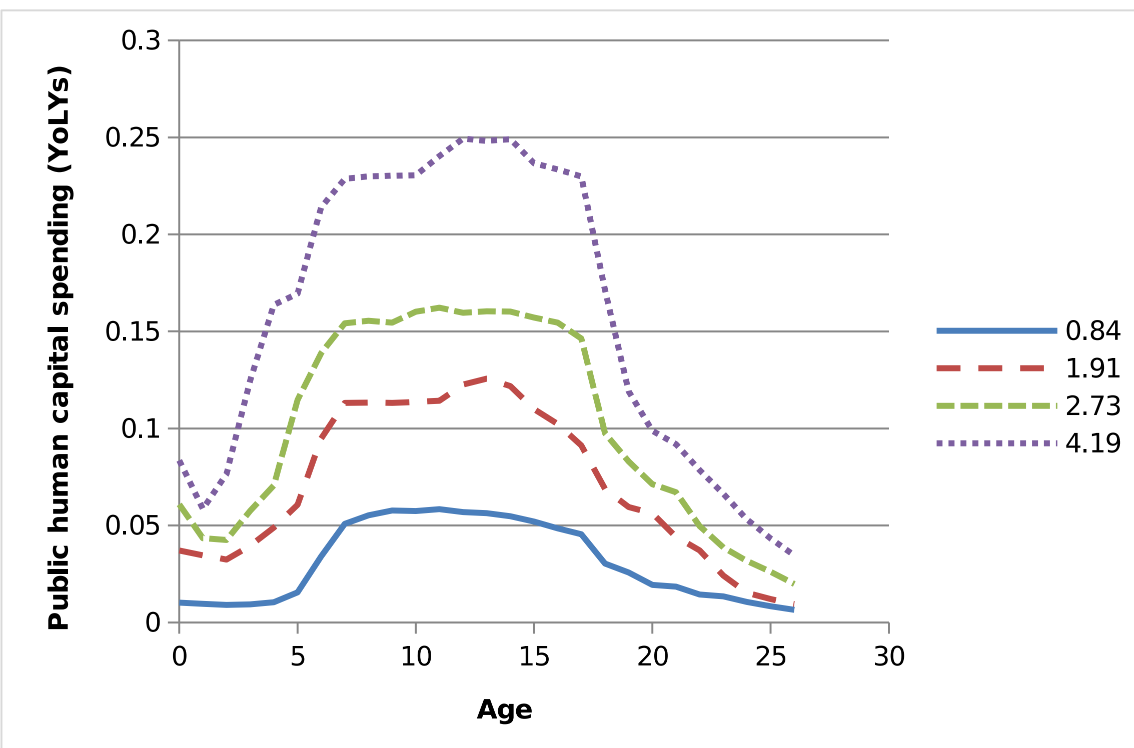


Figure A.1. Normalized public human capital spending by age for four country groups classified by public synthetic cohort public spending on human capital expressed in YoLYs. Source: Calculated by authors. File: nta data.xls

Values are projected (forward and backward) by linearly interpolating using the synthetic cohort values. For values below the minimum hki_sc value, the “model” profile for the lowest value is scaled to match the observed hki_sc value. Likewise, high profiles are obtained by rescaling the highest age profile.

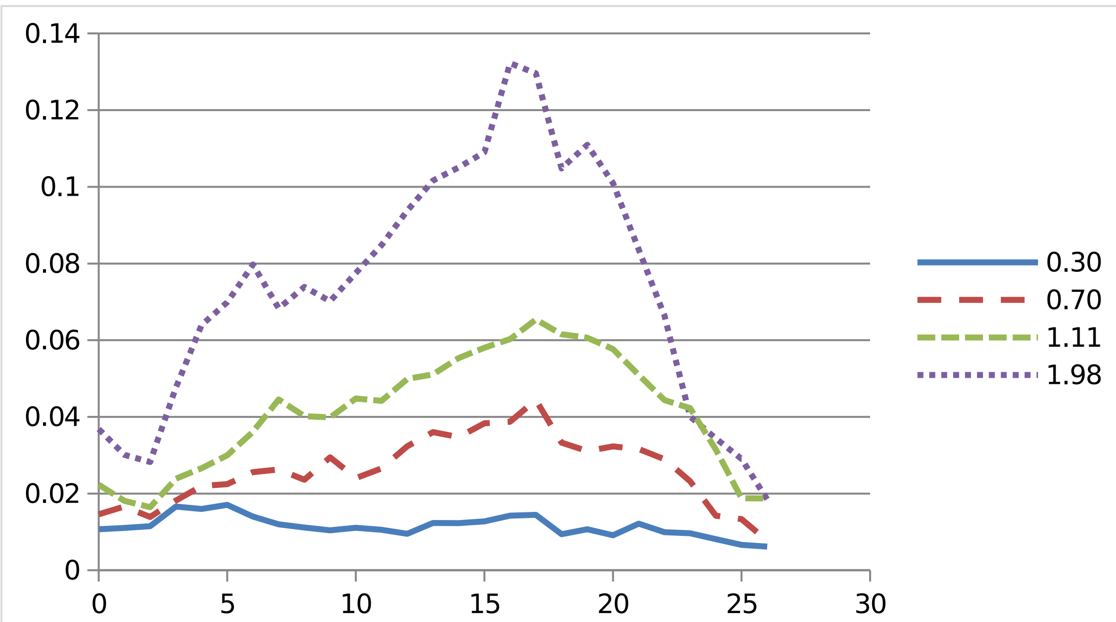


Figure A.2. Normalized private human capital spending by age for four country groups classified by private synthetic cohort public spending on human capital expressed in YoLYs. Source: Calculated by authors. File: nta data.xls

One might expect to see spending increasingly concentrated at older ages (tertiary levels) in countries with high human capital spending. We don’t find that to be the case. There are very substantial increases at young ages – pre-school and early elementary school ages. The mean age of human capital investment drops from 13.7 for the lowest spending countries to 12.4 for the highest spending countries. Public investment mean ages drop from 13.0 years to 12.5 for the highest spending countries. For private human capital investment, the mean age drops from 14.0 for countries with very low HK spending to a mean age of 12.8 for countries with the highest human capital spending.

Estimating labor supply (l(x))

Labor supply is estimated for the baseline year for each country using the age profile of labor income and an estimate of the cumulative human capital investment for persons at each age in the profile year. Labor income by age consists of the return to human capital and the return to “raw labor”. It follows directly from the MRW production function that the labor income is equal to:

$$
\begin{aligned}
Y_H(x)+Y_l(x) &= \beta Y\left(\frac{H(x)}{H}\right)+(1-\alpha-\beta)Y\left(\frac{L(x)}{L}\right)\\
H(x) &= hkicum(x)l(x)N(x)\\
L(x) &= l(x)N(x)
\end{aligned}
$$

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Where $Y_H(x)$ is total income accruing to human capital and $Y_l(x)$ is total income accruing to raw labor. Dividing both sides by total human capital and labor income combined and noting that the share of capital income is α yields:

$$
\frac{Y_H(x)+Y_l(x)}{Y_H+Y_l}=\frac{\beta}{1-\alpha}\left(\frac{H(x)}{H}\right)+\frac{1-\alpha-\beta}{1-\alpha}\left(\frac{L(x)}{L}\right)
$$

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Substituting the elasticity estimates of 1/3 for each factor and substituting for H and L gives:

$$
\begin{aligned}
2\left(\frac{Y_H(x)+Y_l(x)}{Y_H+Y_l}\right) &= \frac{H(x)}{H}+\frac{L(x)}{L}\\
&= \frac{hkicum(x)l(x)N(x)}{\sum_x hkicum(x)l(x)N(x)}+\frac{l(x)N(x)}{\sum_x l(x)N(x)}
\end{aligned}
$$

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NTA estimates are employed for the age profile of total labor income, the left-hand-side, population estimates by age are available from the UN, cumulative investment in human capital is constructed using methods described immediately below, leaving l(x) to be estimated. We estimate the l(x) values for single years of age from 15 to 80 giving us 65 unknowns with 65 equations. The system is solved using non-linear estimation routines in Stata. (Note that the system is exactly identified and the non-linear routines can be used in Stata although the standard errors are meaningless.)

Constructing historical estimates of cumulative human capital investment

The approach to constructing historical estimates consists of four steps. First, we predict synthetic cohort estimates of human capital investment from 1949 to 2010. Second, we use synthetic cohort estimates and model profiles of age specific human capital investment to construct estimates of human capital investment (public and private) by age from 1950 to 2010. Third, we construct cumulative human capital investment by age in 1949 assuming that investment by age prior to 1949 was less by 1 percent per year. Fourth, given the cumulative spending in 1949 by age and subsequent annual spending we can construct cumulative human capital investment at each age from 1950 to 2010.

We used three approaches to backcasting the synthetic cohort estimates for 1950 to 2010: (1) the regression model based on YoLY(t) and CDR(t); (2) the regression model based on YoLY(t) and TFR(t); and a regression model based on Barro-Lee (BL) estimates of average years of schooling for those 20-24 years of age.

Historical estimates for YoLY were constructed from real per capita GNP data from Maddison (2001). We multiplied by population, multiplied by two-thirds to obtain an estimate of total labor income, and divided by the effective labor force. The CDR and TFR are based on World Population Prospect estimates (United Nations Population Division 2013).

The Barro-Lee based estimates were constructed by regressing ln hki_sc from NTA on average years of schooling for those 20-24 from BL (Barro and Lee 2010). Time series data from BL was used to backcast at five year interval. An annual series was obtained through linear interpolation.

Human capital synthetic cohort values for 1950 to 2010 for the three approaches are compared for Nigeria and China in Figure A.3. There are important differences among the series. In Nigeria, the BL-based estimates rise between 1950 and 2010, but they do not for the TFR- or CDR-based series. We see a gradual decline for the CDR-based series. For China, the TFR-based series rises most steeply while the BL-based system rises more gradually. In both Nigeria and China, the CDR series is qualitatively different in that it hki_sc declines during the 1950s and 1960s as declining infant and child mortality led to a higher child dependency ratio that pushed human capital investment down relatively to labor income.

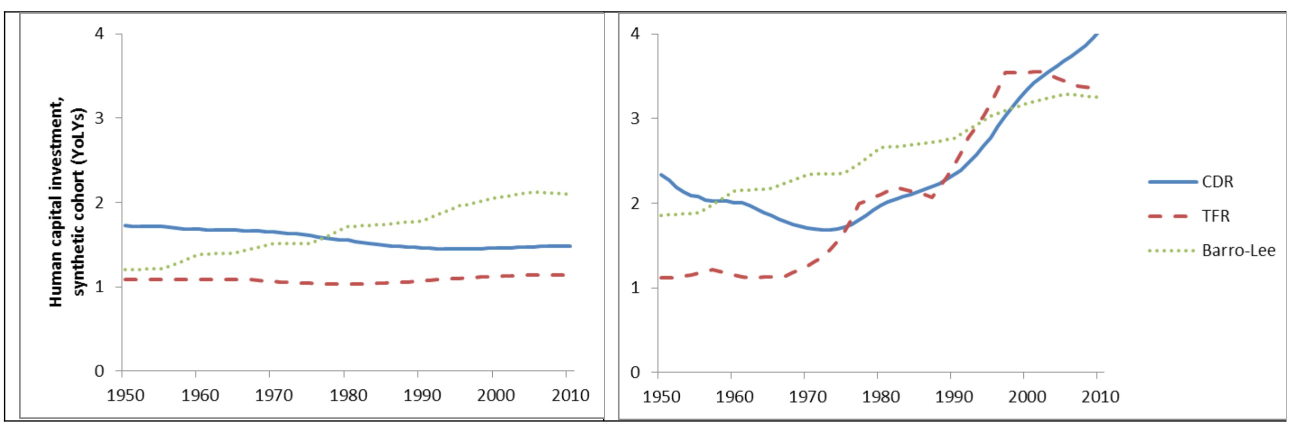

Figure A.3. Predicted values of synthetic cohort human capital investment, Nigeria (left) and China (right), 1950-2010. Three methods are employed based respectively on the child dependency ratio (CDR), the total fertility rate (TFR), and

Barro-Lee (BL) estimates of educational attainment for persons 20-24. See text for more information. Source: Constructed by authors.

Estimates of the effective supply of labor, l(x), for Nigeria and China based on the three historical estimates of human capital investment differ are presented in Figure A.4. The estimated l(x) profiles are very similar to one another. In the Nigeria case, for TFR and CDR estimates educational attainment varies little by age and hence almost all of the variation in labor income is due to variation in the effective labor supply, l(x). In China, younger adults are much more educated than older adults and, hence, the effective labor curve for China is lower than the age profile of labor income at young ages and higher at older ages. As a result, effective labor controlling for human capital differences increases more slowly, peaks later, and is higher at older ages.

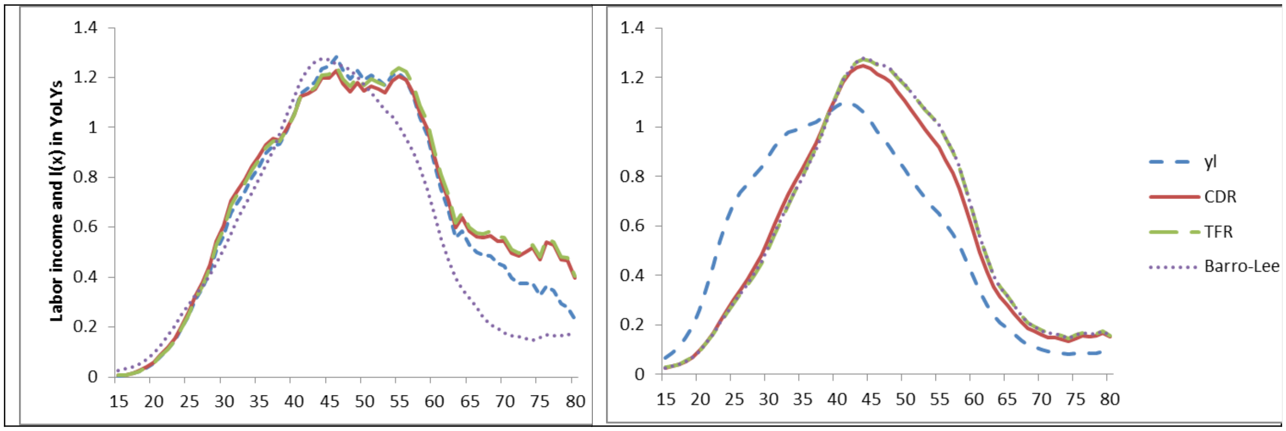

Figure A.4. Per capita labor income by age and predicted effective labor by age (l(x)), Nigeria 2004 and China, 2002. All profiles have been normalized by dividing by the average value of those 30-49. Estimates of l(x) are based on alternative estimates of human capital investment based on historical data using TFR and YoLY, CDR and YoLY, or Barro-Lee estimates of educational attainment of those 20-24 years old. TFR estimate is indistinguishable from the Barro-Lee estimate in the China graph.

Human capital data

Table A.1. Human capital spending by country, recent year. All values are synthetic cohort estimates and expressed in YoLYs, the average labor income of persons 30-49. Education is the sum of age-specific values for ages 3 to 26 and health is the sum of age-specific value for ages 0 to 17. Source: www.ntaccounts.org.

	Public		Private	
	Education	Health	Education	Health
Argentina	1.58	0.71	0.51	0.47
Australia	2.24	0.46	0.99	0.11
Austria	3.35	0.40	0.16	0.07
Brazil	1.65	0.53	0.72	0.10
Cambodia	0.63	0.09	1.05	0.28
Canada	3.62	0.54	0.36	0.17
Chile	1.55	0.43	1.06	0.13
China	1.38	0.19	1.43	0.23
Colombia	2.31	0.54	1.34	0.27
Costa Rica	1.99	0.53	0.60	0.12
Ethiopia	0.27	0.12	0.90	0.03
Finland	2.97	0.47	0.04	0.14
France	3.15	0.44	0.21	0.06
Germany	2.31	0.59	0.28	0.09

Ghana	1.16	0.23	0.89	0.08
Hungary	3.30	0.45	0.28	0.06
India	0.82	0.25	0.53	0.15
Indonesia	1.24	0.13	0.75	0.09
Italy	3.88	0.80	0.38	0.09
Jamaica	1.53	0.17	1.70	0.10
Japan	3.46	0.42	1.22	0.19
Kenya	0.87	0.10	0.12	0.22
Mexico	2.10	0.23	0.94	0.07
Mozambique	1.21	0.16	0.12	0.08
Nigeria	0.17	0.04	1.04	0.87
Peru	1.42	0.52	1.09	0.30
Philippines	0.96	0.14	1.08	0.16
Senegal	0.54	0.11	0.28	0.18
Slovenia	4.09	0.50	0.41	0.04
South Africa	1.71	0.25	0.59	0.31
South Korea	1.76	0.26	2.14	0.12
Spain	2.87	0.46	0.53	0.08
Sweden	4.84	1.02	0.14	0.03
Taiwan	1.66	0.44	2.79	0.25
Thailand	2.35	0.16	0.35	0.44
United Kingdom	2.49	0.46	0.63	0.00
Uruguay	1.65	0.64	1.72	0.61
US	2.61	0.26	0.52	0.48
Vietnam	0.49	0.03	1.55	0.31

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